Decarbonisation strategy: what might be the least costly and most effective way for developing low carbon economy in a "Broader Energy Europe" and beyond considering decarbonized gas as part of the solution

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1 - 4 October 2019 (Wrap-up session, 03.10.2019), Saint Petersburg

Evolution of EU low-carbon policy/vision – and prospects of Russia-EU cooperation (incl. within GAC WS2): challenges & bifurcations

Gas-fired back-up to RES

Internal competition for H2 market niche between **three (not two)** key technologies

Primary energy | **End-use energy**

Yesterday in EU (yesterday & today beyond EU)

Chemical (NRES) + Electrical (RES) → CO2 → Chemical; Electrical; Electrical (RES)

First EU energy vision (up to end-2017)

Electrical (RES) → Electrical (RES)

EU (1) Energy Future = *"digital, electrical, renewable" => RES-based => evolution of the thesis since then*

Second EU energy vision (since early 2018)

Electrical (RES) → Electrical (RES); Chemical: H2 (EU: "green" H2)

EU (2) Energy Future = *"digital, electrical, renewable + gaseous" => RES + decarbonized gases =>* ***what's that?***

Current state of debate (in EU/GAC WS2) – to identity challenges & bifurcations (***Third EU energy vision ?***)

Electrical (RES) + CC(U)S + Chemical (NRES => gas) → CO2 / w/o CO2 → Electrical (RES); **Chemical: H2 (EU: "green" H2)**; Electrical (gas-fired); **Chemical: H2 (EU: "blue" H2)**

…in competition with imported LNG to EU:
(1) EU Quo Vadis => barriers for Rus gas?, **(2)** US LNG => unfair competition in EU?
(3) UA transit post-2019 – if no balanced decision

Area of potential growth of Rus gas supplies to EU…

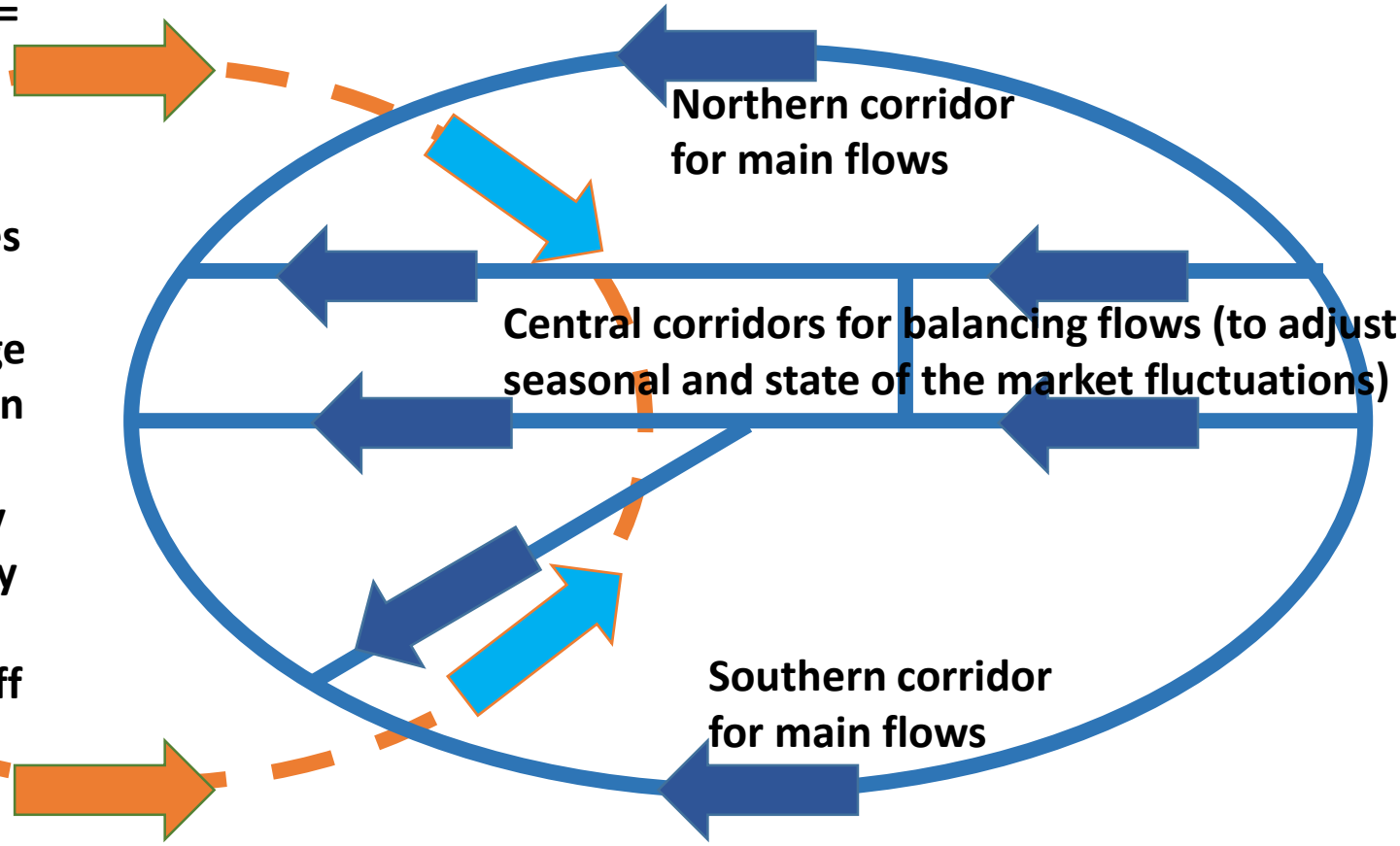
NRES=non-renewable energy sources
RES=renewable energy sources
CC(U)S=carbon capture, (utilization), storage/sequestration

A.Konoplyanik, IGU Stategy Comm meeting, SPB. 03.10.2019

Two forming circles of future gas supplies to Europe: (i) "disrupted" circle of global LNG supplies to Europe and (ii) integral with internal backup circle of Russian pipeline gas supplies within "Broader Energy Europe"

=> Europe for Russian pipeline gas supplies = destination market;

=> Europe for import LNG (US LNG) supplies = balancing market within global arbitrage deals (plus destination market in Eastern Europe with "security premium" for delivery "molecules of freedom" → to take-off a competitor, i.e. Rus pipe gas



LNG

Regasified LNG

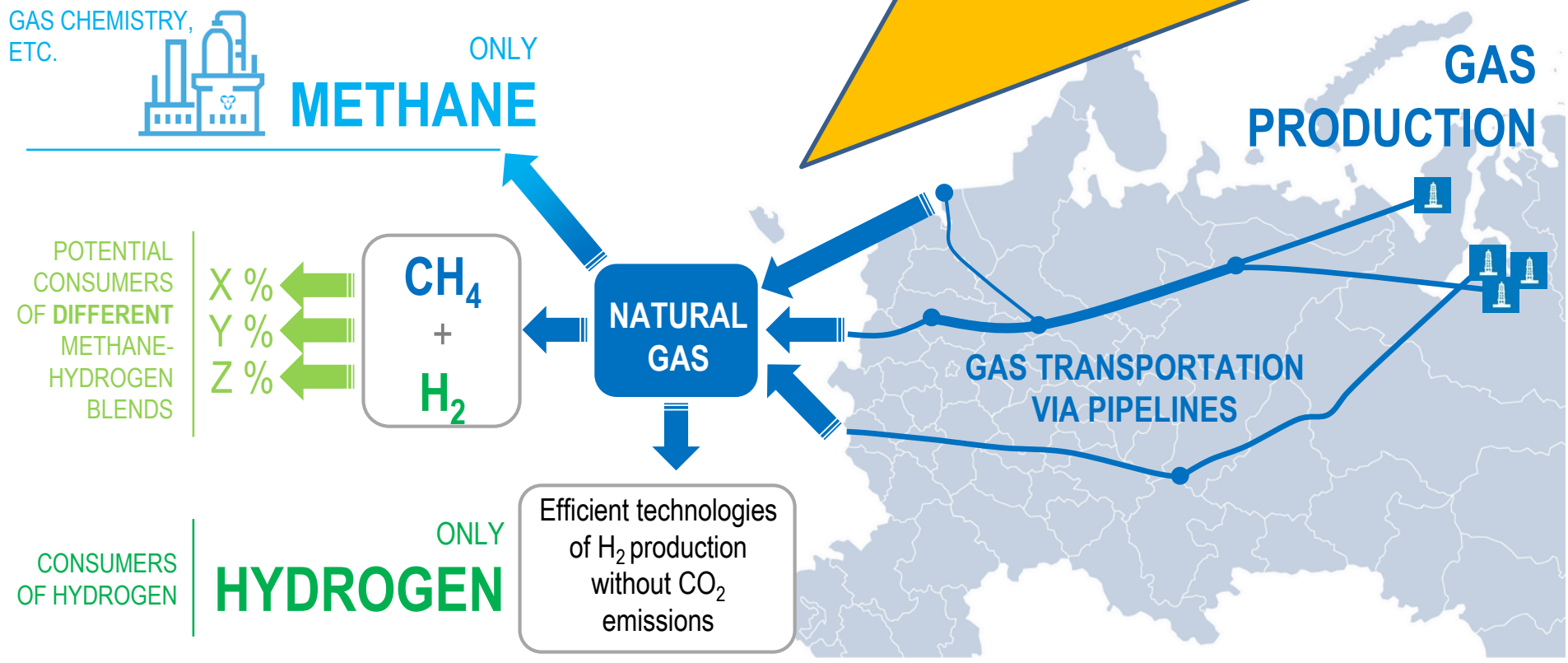
Pipeline gas

Supply circle based on LNG (US LNG): to lock-up in the East – to supersede Russian gas from Eastern Europe

Supply circle based on Russian pipeline gas: to lock-up in the West to increase security of supplies

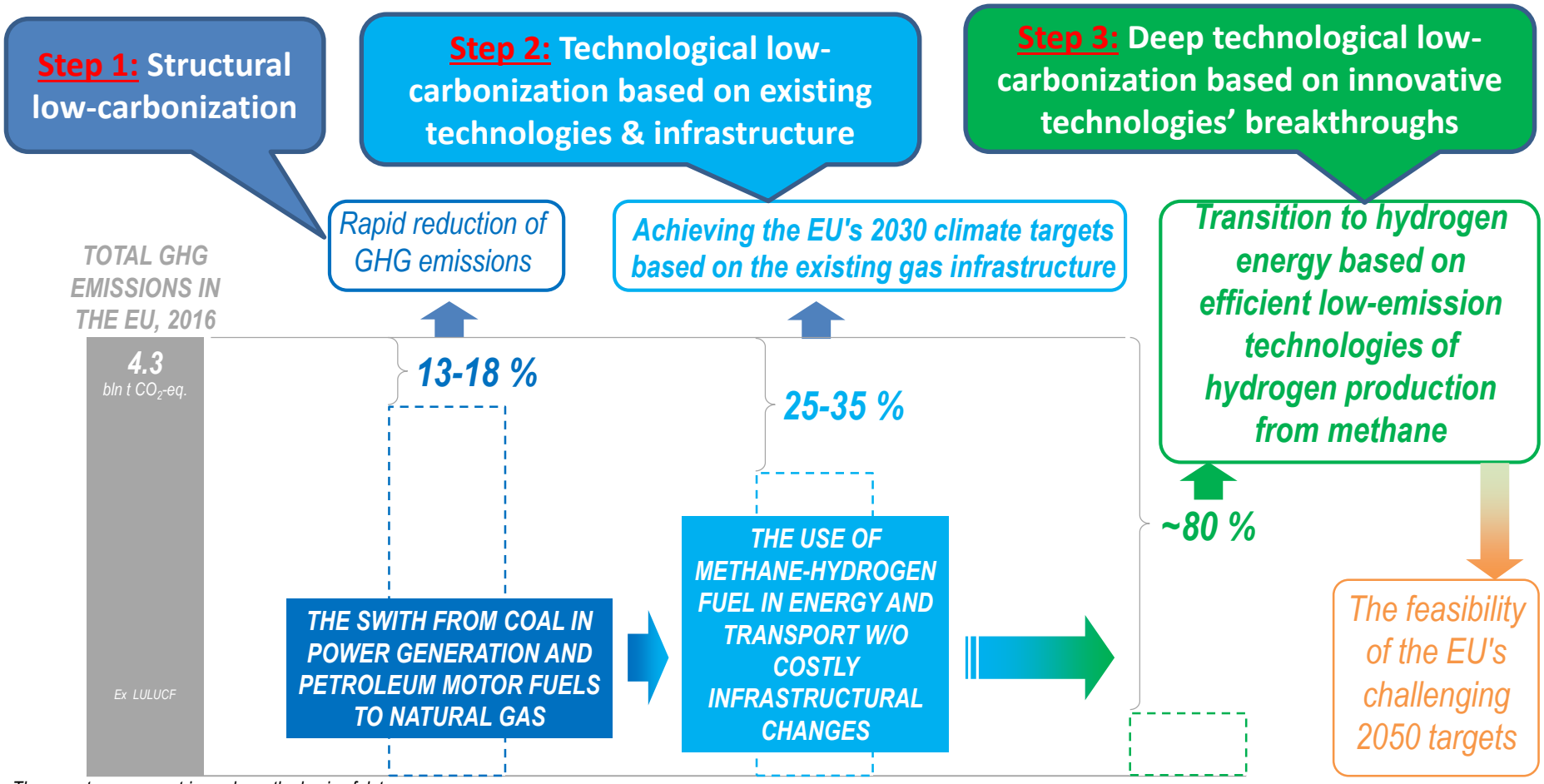
WHERE to decarbonise: selection of location for H2 production

80% CO2 emissions within Russia-EU cross-border gas value chain are downstream, at consumer end, within EU => low-carbonization downstream (at end-use, within EU) based on Russian gas export & (export of Russian, if commercialized & competitive) no-CO2 technologies of H2 production => fair competition, technological neutrality, mutual complementarity of "blue H2" technologies **with** (Norway/Equinor path => incl. CCS) & **without** (Russia/Gazprom path => no CCS) CO2 emission



Source: O.Aksyutin, A.Ishkov, K.Romanov. Potential of natural gas decarbonization: Russian view of the cross-border gas value chain. // 27th meeting of GAC WS2, Brussels, 07.12.2018 (www.fief.ru/GAC)

HOW to decarbonize: Gazprom's three-steps cooperative vision ("Aksyutin's pathway")

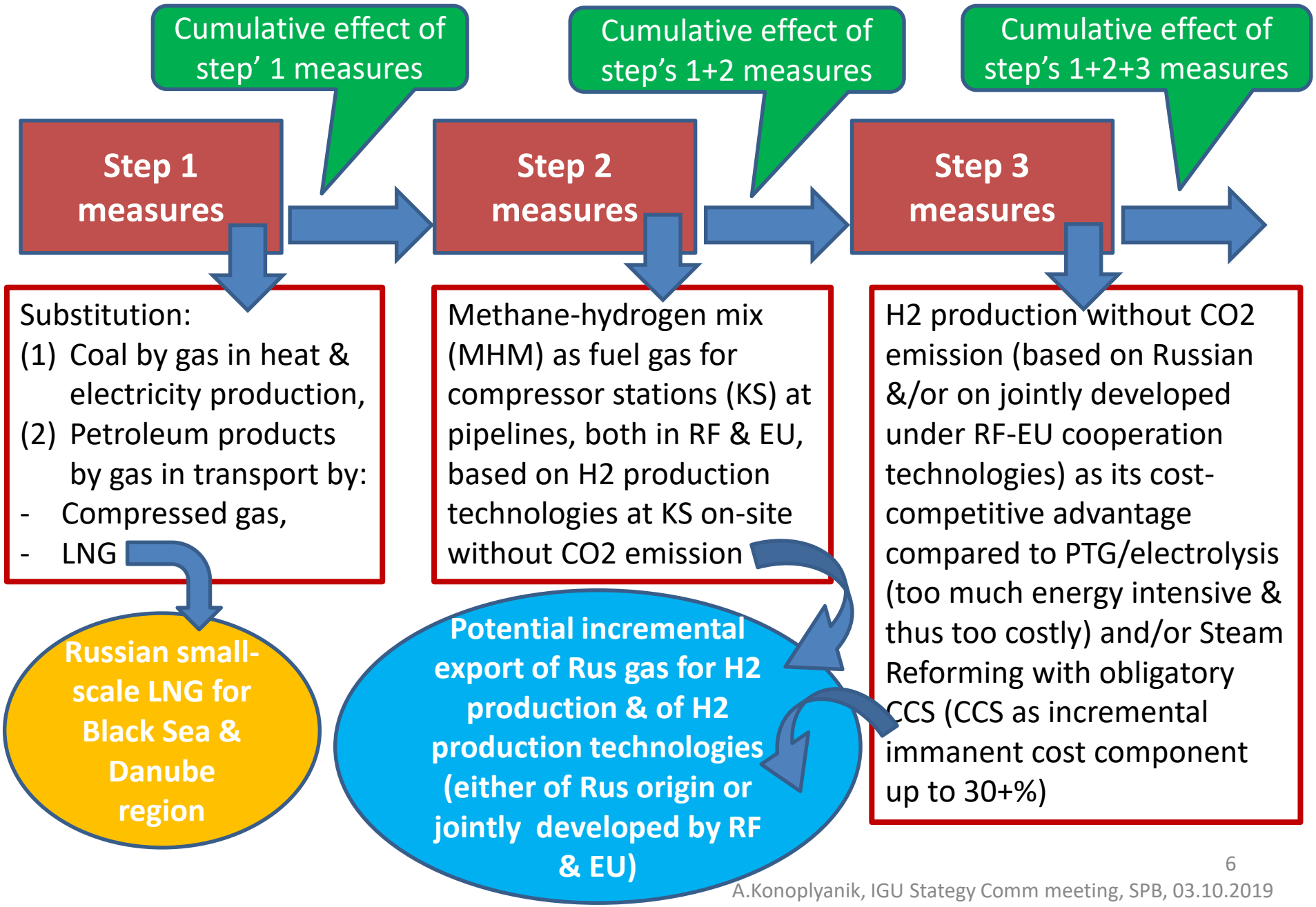


The expert assessment is made on the basis of data on:

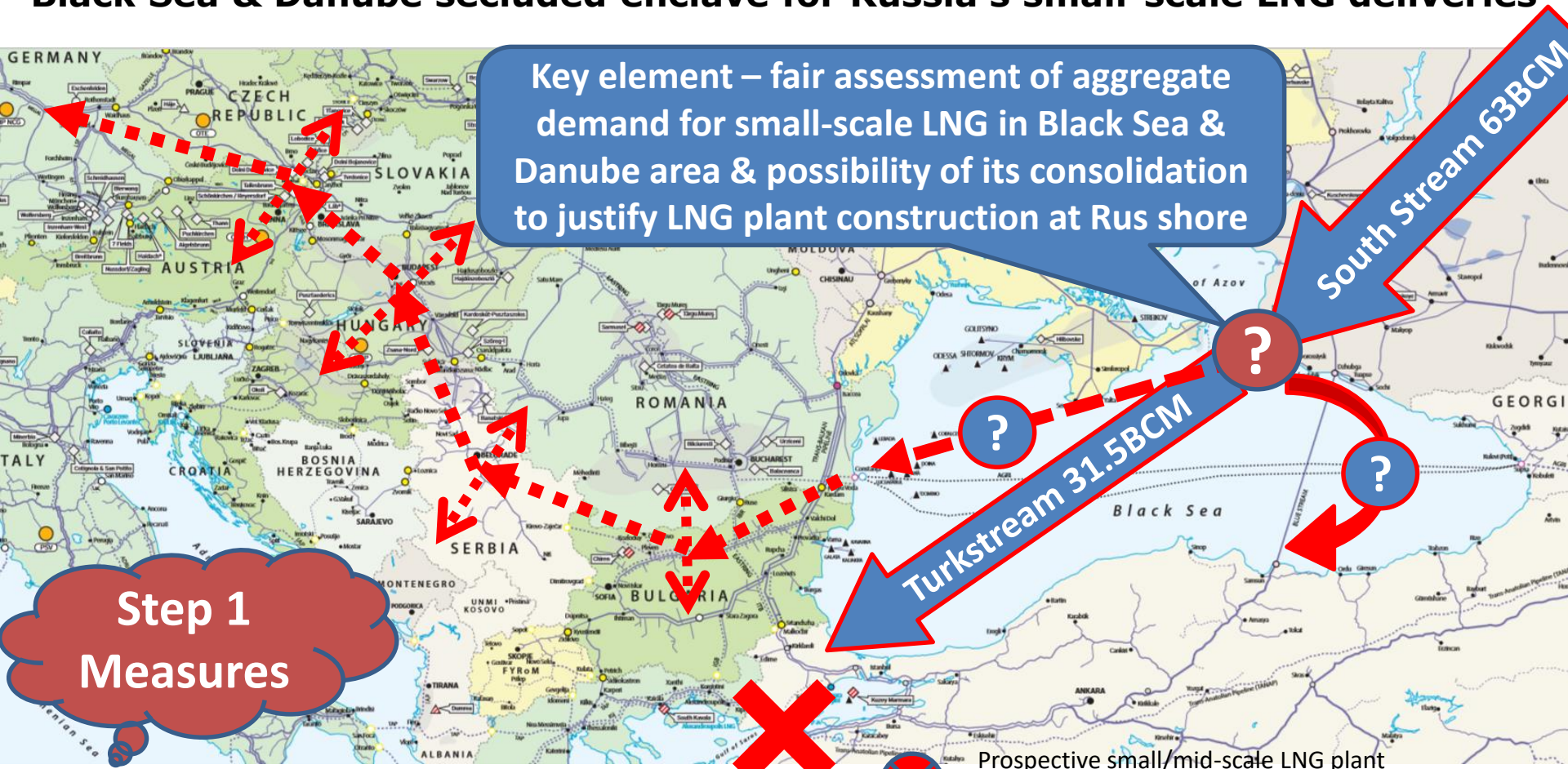
- *Carbon intensity from different fuels (U.S. Energy Information Administration estimates);*
- *Carbon footprint of various motor fuels (European Natural gas Vehicle Association report, 2014-2015);*
- *EU GHG emissions (1990 – 2016 National report on the inventory of anthropogenic emissions by sources and GHG removals by sinks not controlled by the Montreal Protocol , IEA)*

Source: O.Aksyutin. Future role of gas in the EU: Gazprom's vision of low-carbon energy future. // 26th meeting of GAC WS2, Saint-Petersburg, 10.07.2018 (www.fief.ru/GAC); PJSC Gazprom's feedback on Strategy for long-term EU greenhouse gas emissions reduction to 2050 // https://ec.europa.eu/info/law/better-regulation/initiatives/ares-2018-3742094/feedback/F13767_en?p_id=265612

How to implement three-steps "Aksyutin's pathway"?



Turkey' s decision on closure of the Straits for LNG-carriers and Russia's change from South Stream to TurkStream as a precondition for forming of Black Sea & Danube secluded enclave for Russia's small-scale LNG deliveries



Turkey's prohibition for LNG-carriers to pass though the Straits in both directions

Small/mid-scale LNG supplies towards Danube

Small/mid-scale LNG supplies through Danube (LNG delivery as cassette modules to gas stations and for river ships' bunkering)

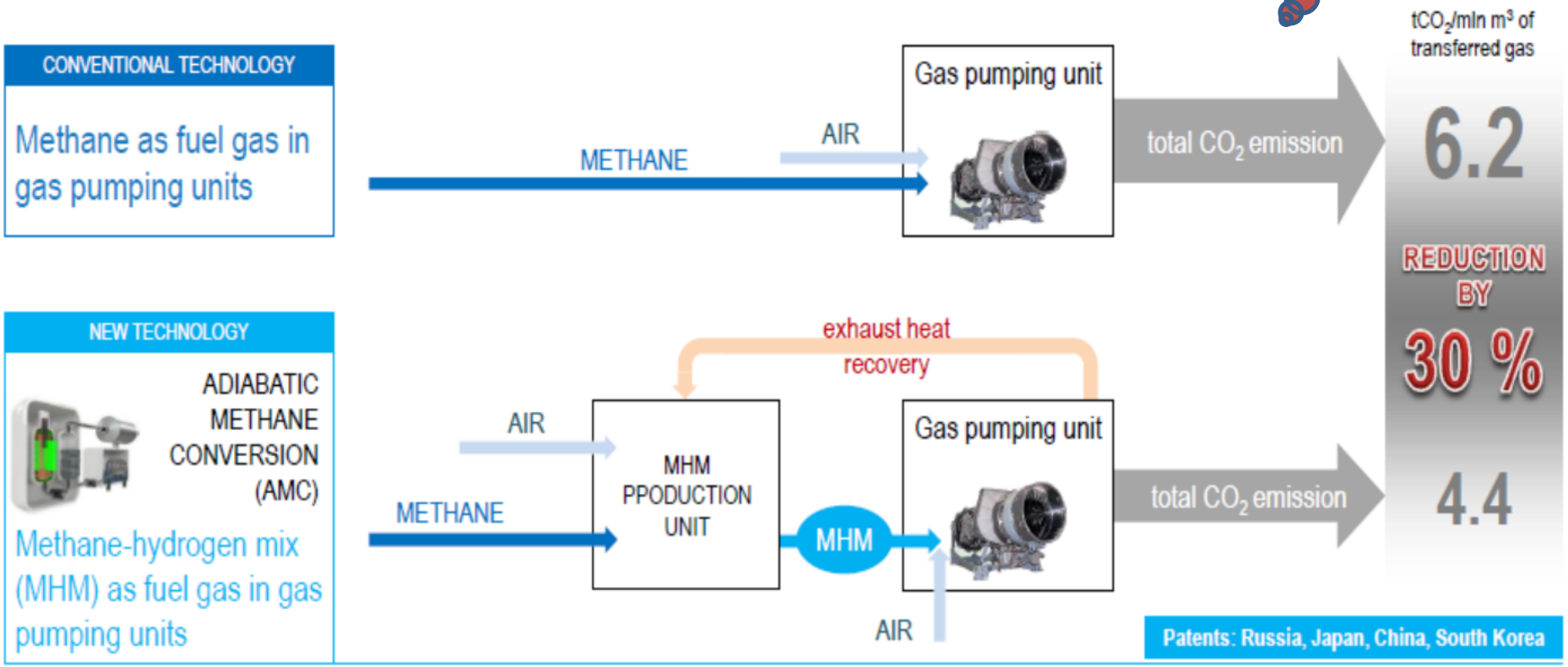
Prospective small/mid-scale LNG plant (onshore/offshore)

Ships bunkering (sea vessels & sea-river vessels) in Black Sea water area & for entry to Mediterranean water area & to rivers of the Black sea & Volga-Don basins; small-scale LNG supplies to littoral cities

LNG gas stations: for heavy lorries for long hauls (intercity) & intraurban transport (intracity)

ADIABATIC METHANE CONVERSION

Step 2 Measures



8

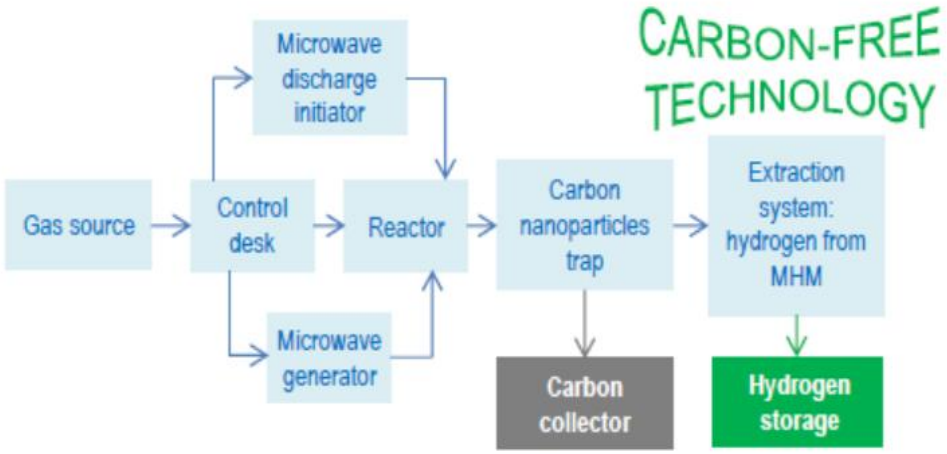
Expert review by the Center for Integrated Development of Technologies and Energy Technology Systems (KORTES Center LLC), Gazprom-Geotekhnologii LLC

Source: O.Aksyutin. Future role of gas in the EU: Gazprom's vision of low-carbon energy future. // 26th meeting of GAC WS2, Saint-Petersburg, 10.07.2018 (www.fief.ru/GAC)

HYDROGEN PRODUCTION IN A LOW-TEMPERATURE NON-EQUILIBRIUM PLASMA

Step 3 Measures

The impact of low-temperature non-equilibrium microwave-induced plasma on hydrocarbon gas molecules



CARBON-FREE TECHNOLOGY

PROTOTYPE PLANT

CARBON MATERIAL

CAPACITY OF:
- hydrogen – up to 1 м3/h;
- carbon material – up to 80 g/h

The hydrocarbon gas conversion takes place in a closed plasma-chemical flow reactor **in the absence of oxygen** and at ambient pressure

9

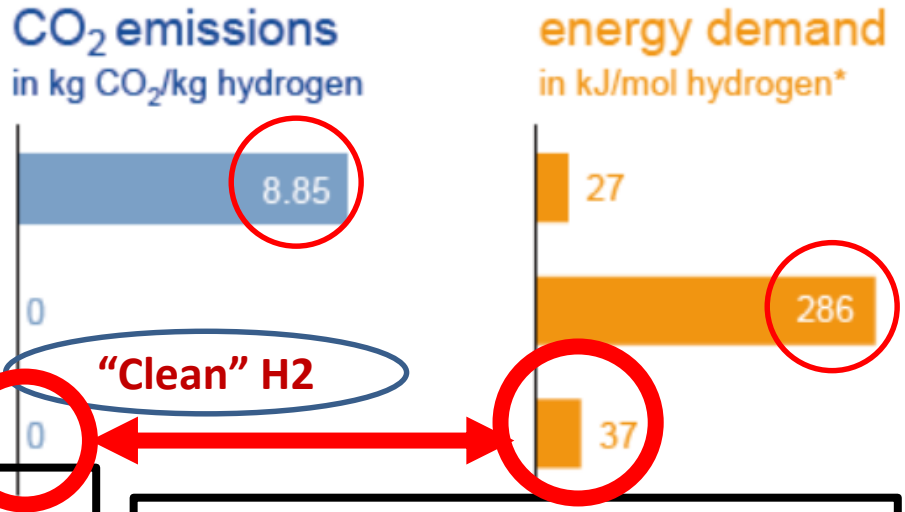
Source: NATIONAL RESEARCH TOMSK POLYTECHNIC UNIVERSITY

Source: O.Aksyutin. Future role of gas in the EU: Gazprom's vision of low-carbon energy future. // 26th meeting of GAC WS2, Saint-Petersburg, 10.07.2018 (www.fief.ru/GAC)

3 key today's technologies of H2 production

CC(U)S is needed!!! => additional imputed costs (CAPEX + OPEX) => add. 20/30+%

Steam reforming of natural gas	$CH_4 + 2H_2O \rightarrow 4H_2 + CO_2$
Water electrolysis	$2H_2O \rightarrow 2H_2 + O_2$
Methane pyrolysis	$CH_4 \rightarrow 2H_2 + C$



Water electrolysis: water as feedstock => "clean" H2 (*):
- First small industrial-scale plants
- Very high energy intensity (8-10 times higher to SR/MP)

Steam reforming: Fossil fuel as feedstock => not-"clean" H2
- Main (95%) H2 production method today at global level
- Low energy intensity
- **BUT:** CO2 emissions (globally ~1% of the anthropogenic GHG emissions comes from steam reforming) =>
- CC(U)S is needed!!! => additional costs (CAPEX + OPEX)

Methane pyrolysis: NG as feedstock => "clean" H2 (*):
- First pilot plants
- Low energy intensity
- Solid carbon as 2nd product => Outlet needed for 3 kg carbon per kg hydrogen

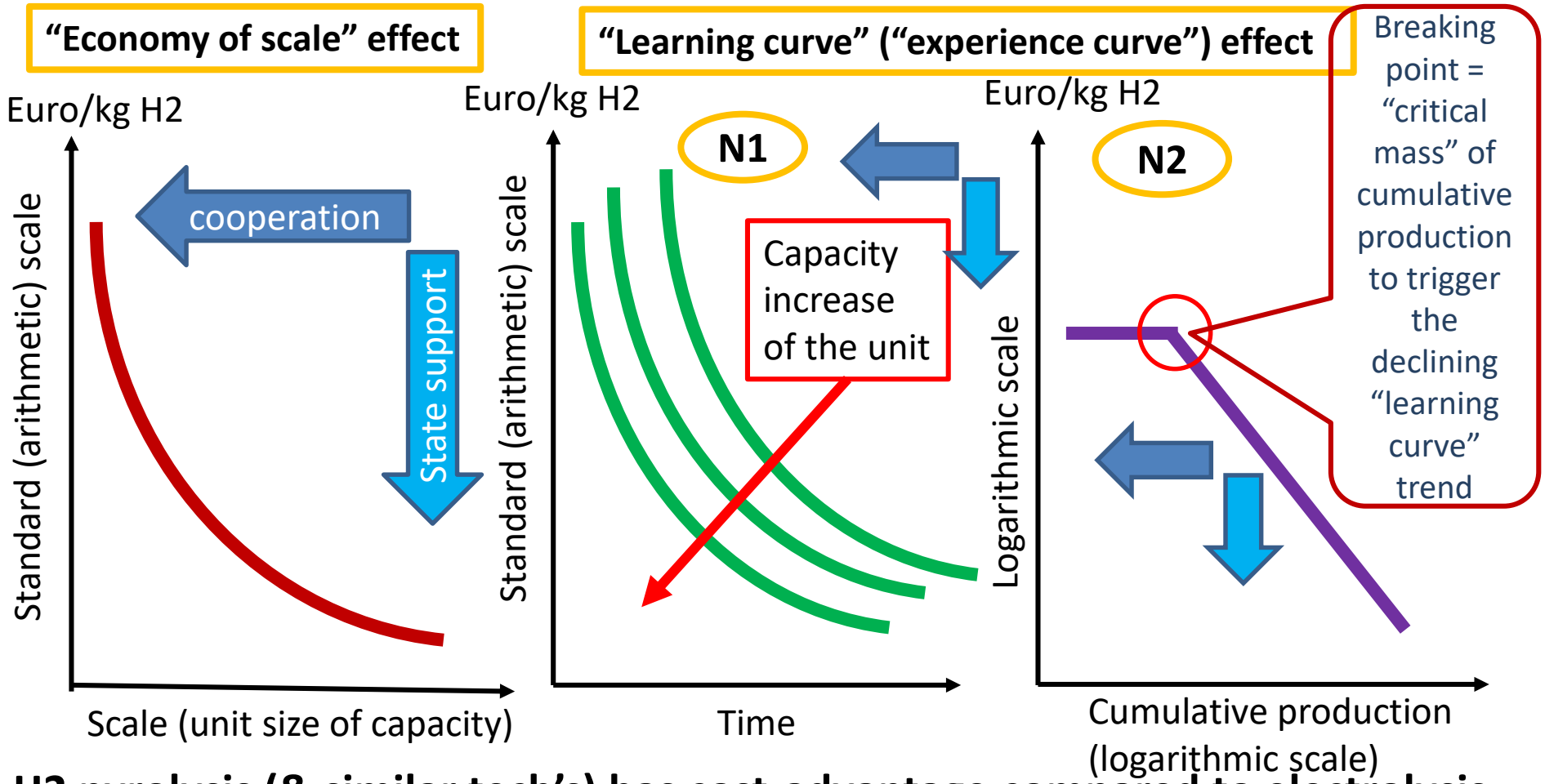
(*) "clean" – means at H2 production stage only

Options for carbon utilization and storage

1. Utilization in major carbon markets
   - Aluminum – positive tests
   - Steel – positive tests
   - Others (tires, concrete admixtures…)
2. Storage/sequestration
   - Soil improver / Terra preta
   - Filling material

Based on: Dr. Andreas Bode (Program leader Carbon Management R&D). New process for clean hydrogen. // BASF Research Press Conference on January 10, 2019 / (https://www.basf.com/global/en/media/events/2019/basf-research-press-conference.html)

What is the current placement of three key H2 production technologies at three types of cost curves? A key possible area of RF-EU research cooperation in decarbonization sphere => WS2 GAC?

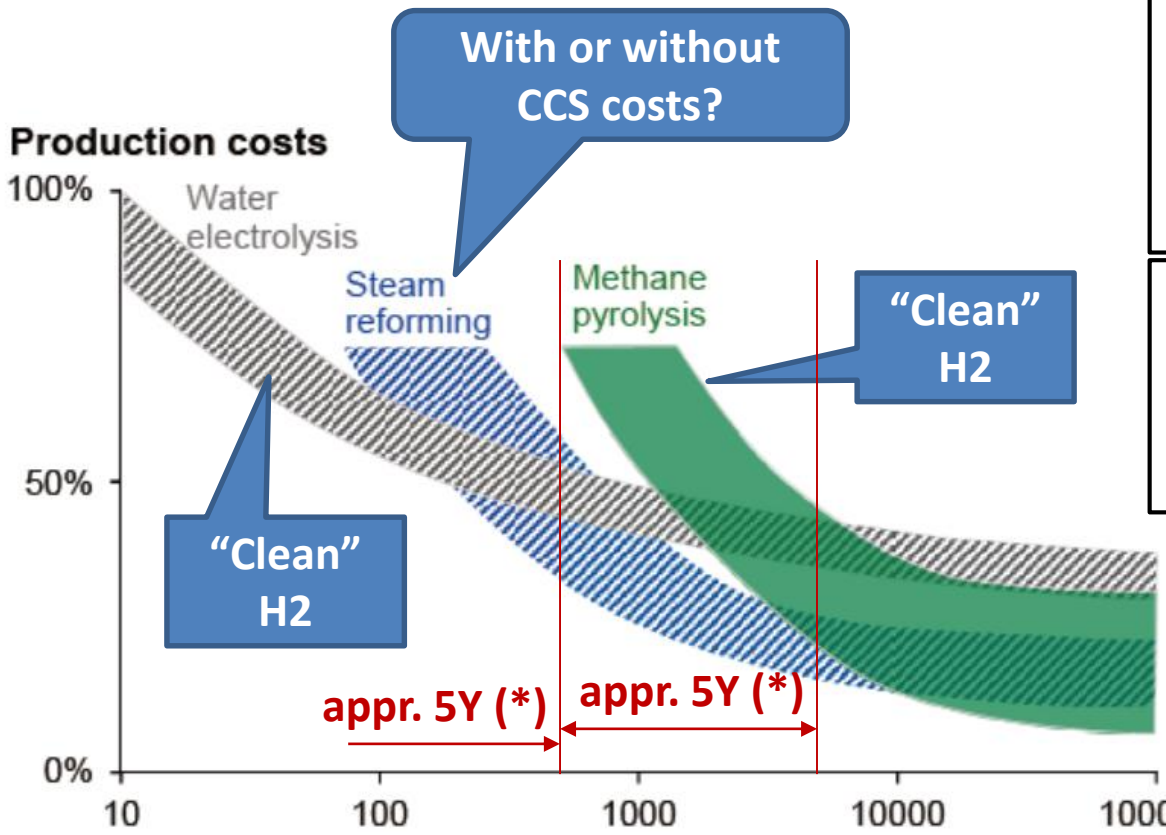


H2 pyrolysis (& similar tech's) has cost-advantage compared to electrolysis (10 times lower energy intensity) and to steam reforming (no need in CCS – 20-30+% saving), but it seems to be placed today at the earlier stage of the cost curves or even not yet been placed at the cost curves

BASF: "Load curves" (economy of scale effect) for three key H2 production technologies

BASF Research Press Conference 2019

Is methane pyrolysis cost competitive?



BASF: 2013 – 2017 Basic, ambitious R&D

- Theoretical and experimental assessment of various reactor concepts
- Carbon sample production on 100 kg scale

Results

- Successful operation on lab scale
- Identification of promising reactor concepts

Successful carbon sample production and application testing

- But: reactor was ruined during sample production

A number of other technical solutions available. See, f.i.: Alberto Abánades. Direct decarbonization of natural gas: A key technology into the energy transition. // GAC WS2, Brussels, 29.03.2019 (https://www.fief.ru/img/files/6_190329_Direct_decarbonization_of_natural_gas.pdf)

Cost estimates for methane pyrolysis depend on value of pyrolysis carbon.

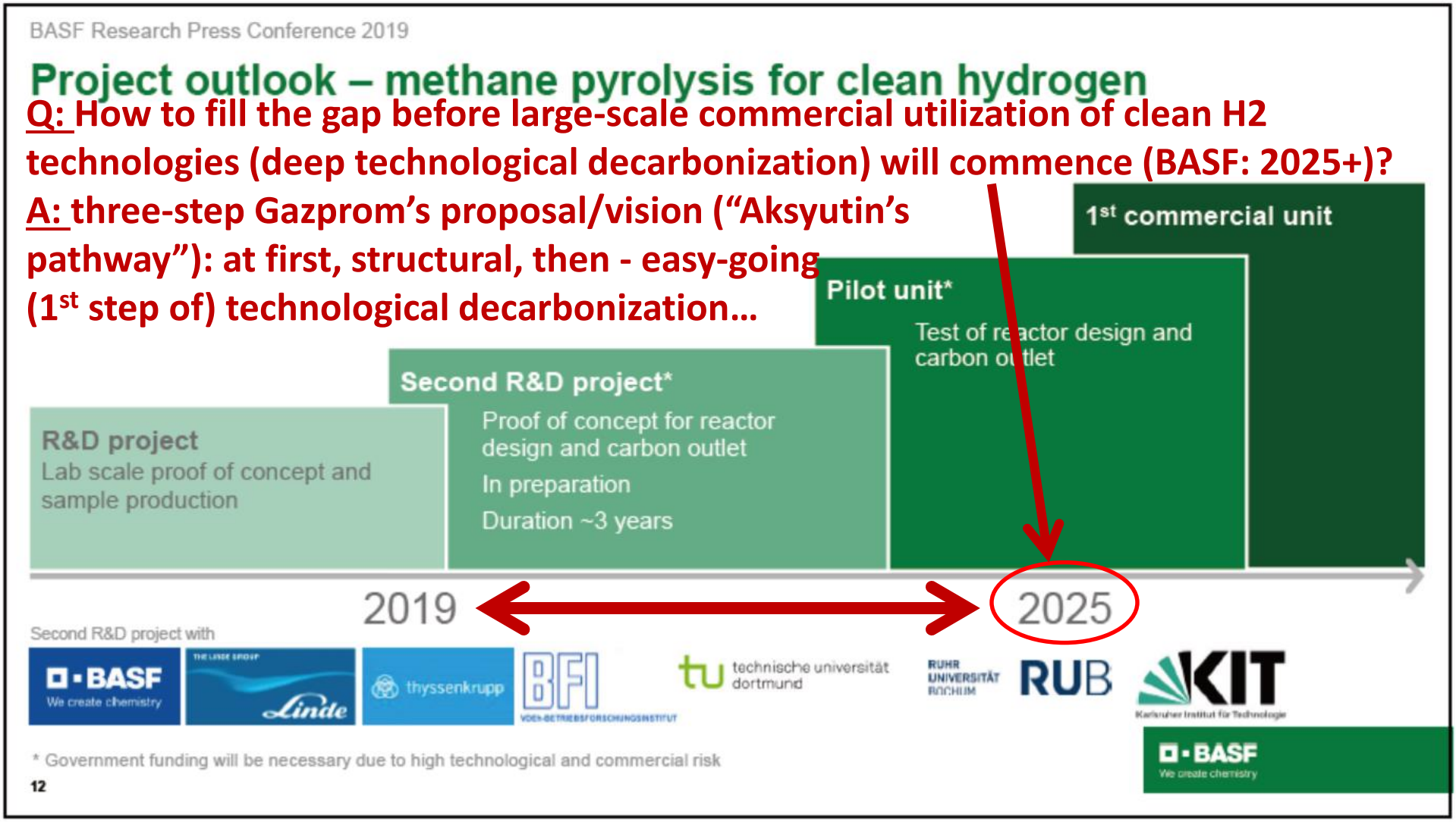
(*) acc. to author's discussion with Alberto Abánades at GAC WS2 meeting, Brussels, 29.03.2019

Carbon sales price or cost for storage is critical

11

BASF We create chemistry

Based on: Dr. Andreas Bode (Program leader Carbon Management R&D). New process for clean hydrogen. // BASF Research Press Conference on January 10, 2019 / (https://www.basf.com/global/en/media/events/2019/basf-research-press-conference.html)



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Approximate potential areas of preferential use of key H2 production technologies in Europe under state regulation based on "technological neutrality" principles

- P2G wind
- P2G solar
- P2G hydro
- P2G nuclear
- Steam reforming plus CC(U)S
- Methane pyrolysis & similar (w/o CO2)

Based on author's conversations with Ralf Dickel

Source of map: ENTSOG

Way forward (from WS2GAC to SC IGU)

- Justified quantitative assessments are needed of economic & ecological effects for three key H2 production technologies
  - Joint RF-EU research is most reliable/trusted (WS2GAC)
- On Methane Pyrolysis (&/or other similar technologies of H2 production w/o CO2 emissions):
  - First demonstration plant in operation needed & a series of first commercial reactors
  - The aim: to reach ASAP the point of "starting decline" at the "learning curve" for methane pyrolysis (& similar technologies)
    - Motivation: all other parameters being equal, methane pyrolysis (& similar technologies) has well-defined competitive advantages compared to P2G (less energy intensive) & methane steam reforming with CCS (less costly)
  - To joint efforts in RD&D by different institutions/companies involved from RF & EU (to obtain synergy effect):
    - Russia: Tomsk, Samara, etc…
    - EU: Karlsruhe, BASF, Madrid, etc…
- To see how this cooperative approach:
  - Can be first used within "Broader Energy Europe" - through WS2GAC
  - Can be afterwards (or in parallel) be expanded beyond "Broader Energy Europe" - through SC IGU

Thank you for your attention!

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