On the New Paradigm of International Energy Development: Risks and Challenges for Russia and Europe on the Way to the Low-Carbon Future

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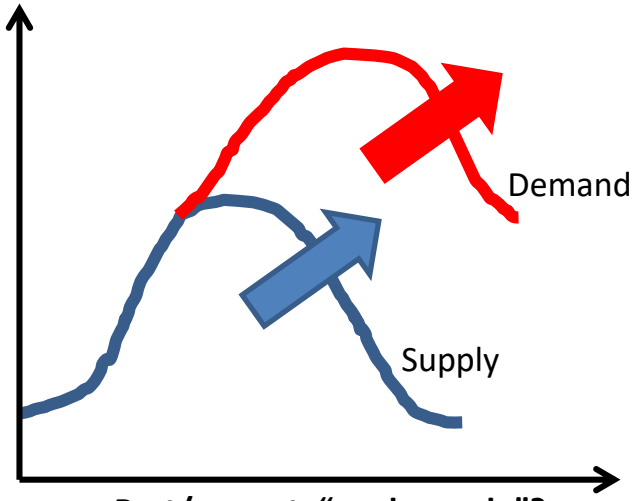
World Energy: The Change of Paradigm?

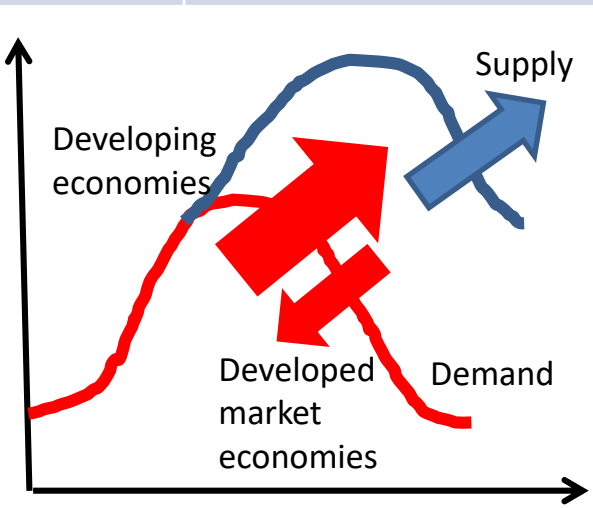
Supply	Demand
- Hubbert's peak (curve) - Hotelling's rent (theorem) - Chevalier's turning point - STP (resource rent, economy of scale)	- Economic growth (industrial-type): industrialization, centralization, concentration - Population growth

Supply	Demand
- STP progress, incl. US shale revolution (from resource rent under economy of scale to technological rent) => Hotelling anti-theorem	- Four steps in departure from oil since 1970-ies (cumulative effect) - Energy efficiency (delinking energy demand & economic growth, post-industrial-type of economic growth) - COP-21/24 (upper limit for emissions) - New type of economic growth in the poorest developing countries (non-industrial, decentralized) & post-industrial in developed market economies



Past/current: "peak supply"?

Future energy resources more costly & limited (depletion rent) => low-cost win more rent, high-cost delayed



From Current to Future: "peak demand"?

Future energy supply less costly & plentiful (partly not in demand?) => competition among suppliers increases => low-cost win, high-cost cut-off

Multi-dimensional competition in energy markets strengthens

Source: A.Konoplyanik

Three global gas revolutions

Two revolutions came from supply-side:

1) US shale (gas & oil) revolution
   - one of the long-term man-made consequences of the oil price shocks of the 1970-ies
   - 10+ reasons why it happened in the US and not elsewhere
   - 10+ its "domino effects" which radically changed (energy) world
2) LNG revolution (formation of global LNG market => global gas market)
   - …as one of "domino effects" of US shale revolution
   - development on the model of global oil market (physical plus paper energy market)
   - Increasing supply flexibility at the cost of increasing risks

One revolution came from demand-side:

3) "green" revolution /decarbonization/low-carbon development (in result of growing importance, up to aggravation, of climate agenda):
   - Technological aspects (mostly RES) with geopolitical subtext (domestic "green/clean" electrons vs. foreign "dirty" molecules), but
     - EU (since 2018): from all-electric renewable future – to "renewable electricity plus decarbonized gases"
   - Regulatory aspects: from unbundling/"atomization" (markets, companies) – to reintegration (re-bundling) of markets & companies with growing low-carbon considerations

These three revolutions have overlapped on top of long-term effect of materialized consequences of adaptation of world economy to oil prices' shocks of the 1970-ies

⇒ New more competitive energy environment is being formed; it is more difficult for producers of non-renewable energies (fossil fuels) to find its place in compressing competitive niche

   ⇒ ***Dilemma for Russia: to leave the area of its current competitive advantages OR to stay within non-renewable energy niche on the new competitive basis?***

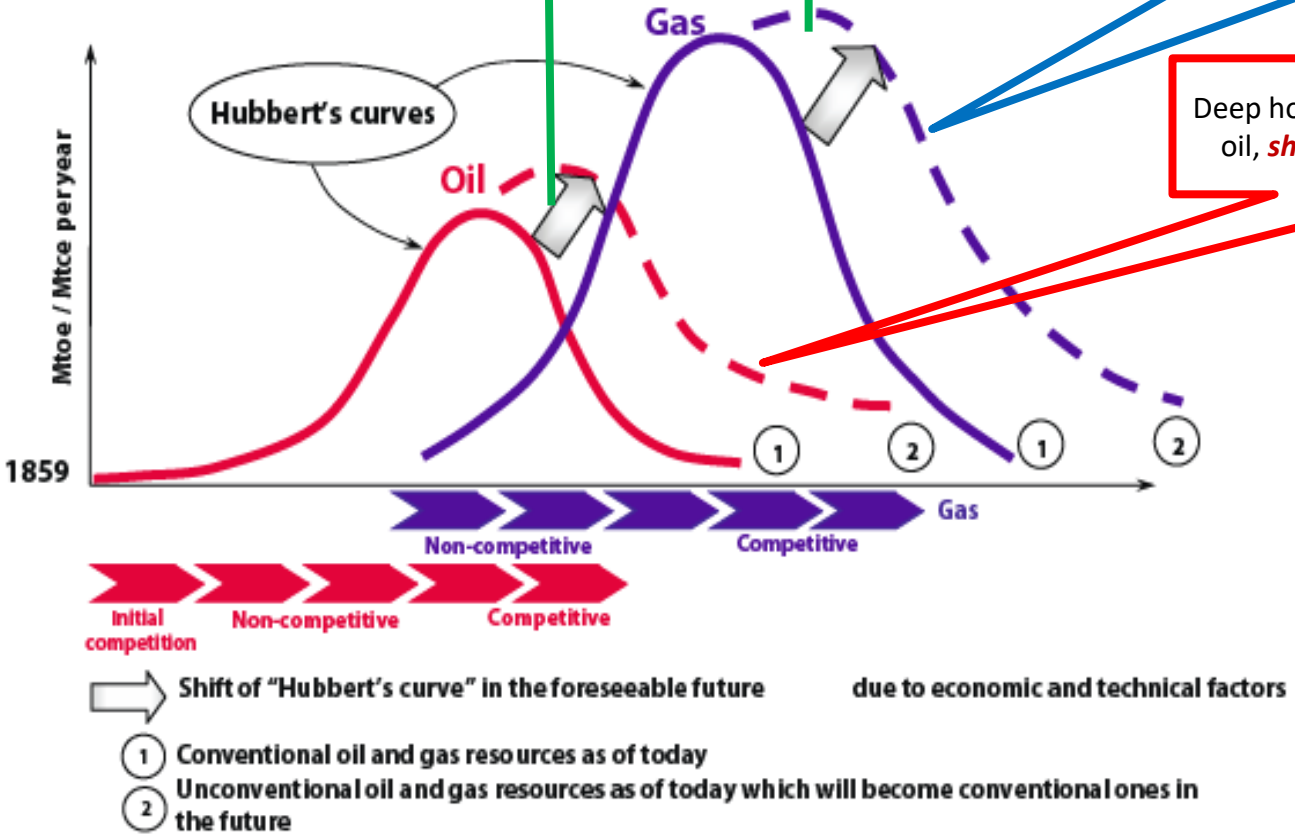
   ⇒ Russia has its competitive niche which allows this country to monetize its vast non-renewable energy resource (incl. most clean – natural gas), but on the new technological basis => Hydrogen as one of the solutions

Economic interpretation of Hubbert's curves (acc. to A.Konoplyanik)

Peak of "Hubbert's curve" is at least TWO investment cycles away

Deep horizons, deep offshore, Arctic, ***shale gas***, CBM, CSM, CMM, biogas, gas hydrates, etc. ...

Deep horizons, deep offshore, Arctic, heavy oil, ***shale oil***, tar sands, GTL, CTL, XTL, ...



Primary source (basic figure (*)): A.Konoplyanik. Energy Security and the Development of International Energy Markets (pp. 47-84), p.49. – in: *Energy security: Managing Risk in a Dynamic Legal and Regulatory Environment.* /Ed. by B.Barton, C.Redgwell, A.Ronne, D.N.Zillman. – International Bar Association / Oxford University Press, 2004, 490p. [74]

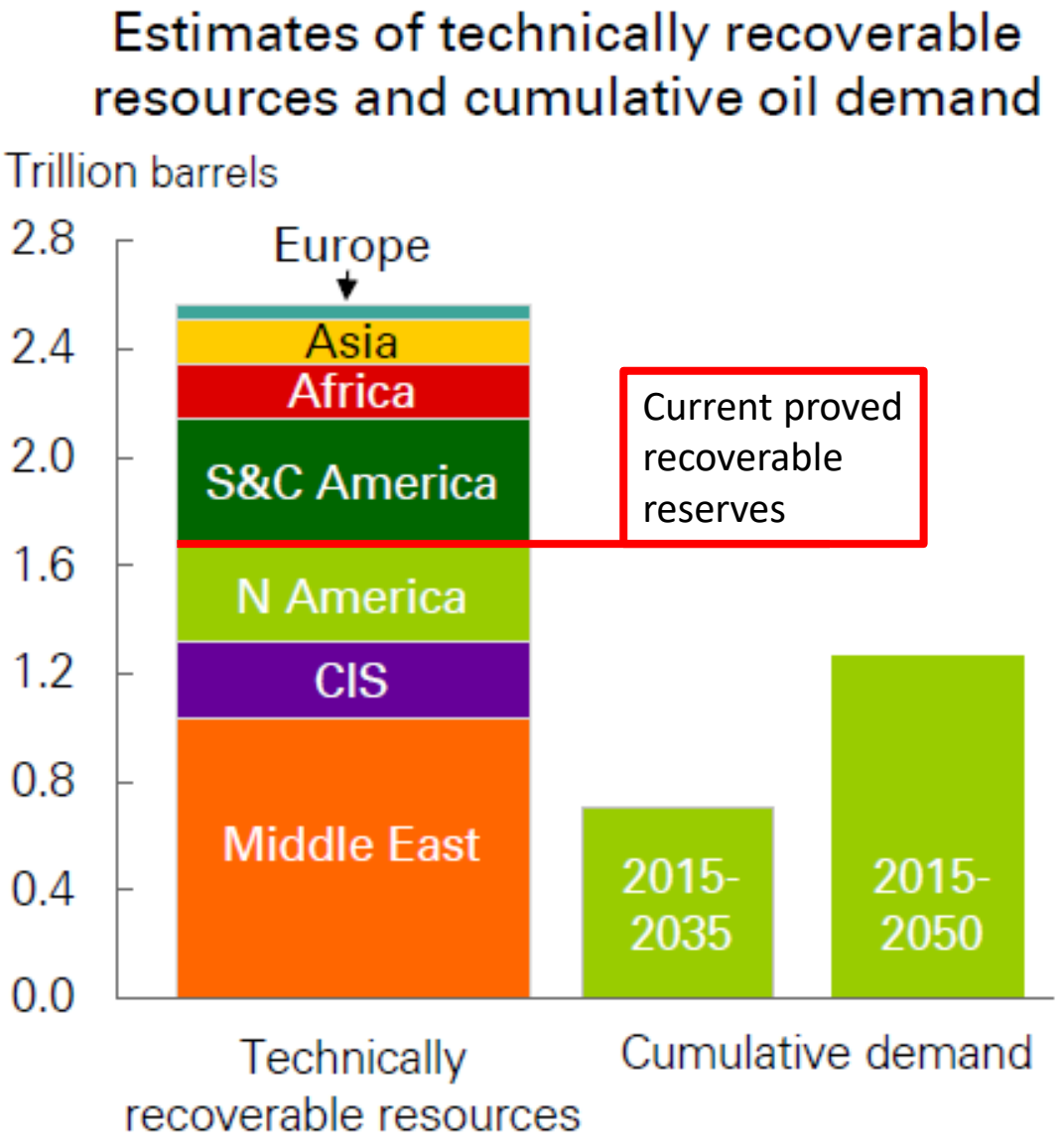
(*) later reproduced in "Putting a Price on Energy…" (ECS, 2007, p.53) [4], where this particular basic picture is taken from

Legend: CBM = coalbed methane (from unmined rock), CSM = coalseam methane (from active coal mines), CMM = coalmine methane (from abandoned coal mines), GTL = gas-to-liquids, CTL = coal-to-liquids, XTL = biomass to liquids

The mankind will not reach Hubbert's peaks in oil & gas at least within **TWO INVESTMENT CYCLES** (first one - based on currently commercialized technologies, second one – on those yet not commercialized technologies that are currently at R&D stage)

Source: A.Konoplyanik

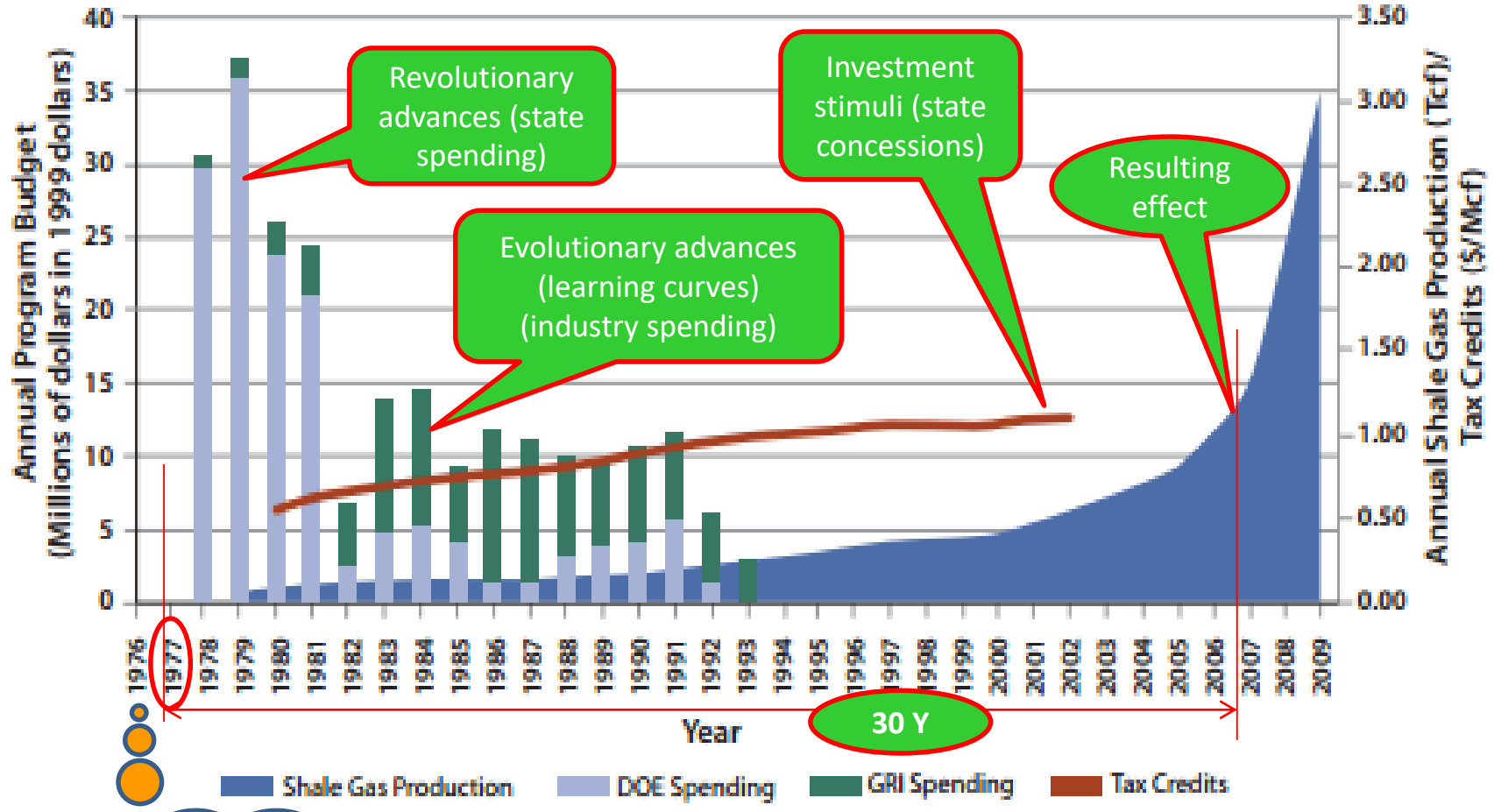
There is no ground for "peak supply" concerns already today, acc. to BP



According to BP, world technically recoverable oil resources exceeds cumulative future forecasted oil demand for 2015-2035 by 3.7 times and for 2015-2050 – by 2 times; proved recoverable reserves – by 2.4 and 1.3 times correspondingly

Source of base graph: Spencer Dale, Group chief economist. BP Energy Outlook, 2017 edition [13] (http://imemo.ru/files/File/ru/conf/2017/07022017/07022017-PRZ-EO17-Presentation-Spencer%20short.pdf)

Role of US state financing in stimulating US shale gas revolution (based on MIT study)



1977 US "Energy Independence" Programme => 1977-2007 = 30 Y

Source of the basic Figure: Figure 8.1 "CBM RD&D Spending & Supporting Policy Mechanisms" from The Future of Natural Gas. An Interdisciplinary MIT Study, 2011, p.163; [44] Figure adapted by this author, first presented in: A.Konoplyanik. "The US Shale Gas Revolution And Its Economic Impacts In The Non-US Setting: A Russian Perspective" (pp. 65-106). – in: "Handbook of Shale Gas Law and Policy"/ed. by Tina Hunter, Intersentia, 2016, 412 pp. [15]

COP-21/24 & New Limits to Growth

- **IEA (WEO 2012):** to limit global warming **by 2°C** (COP-21, Paris, 2015) without large-scale implementation of carbon capture & sequestration (CCS) = not be able to consume (*) **MORE THAN 1/3** of global proven recoverable reserves (PRR) of hydrocarbons (HC) up to 2050
- *OR:* cumulative future CO2 emissions from ***current*** PRR HC volumes are **THREE TIMES HIGHER** than the upper limits of such emissions which are agreed upon in Paris bearing in mind sustainable global development.
- IEA: 2/3 of such potential emissions will come from coal, 22% from oil and products, and 15% from gas.
- Katowice (COP-24, 2018): the limit downgraded to **1.5°C** => competitive quota for using fossil fuels within existing technological chains downgraded as well **below 1/3.**
- 23.09.2019 Russian Prime-Minister D.Medvedev has signed Government Ordinance on adopting Paris agreement (COP-21).

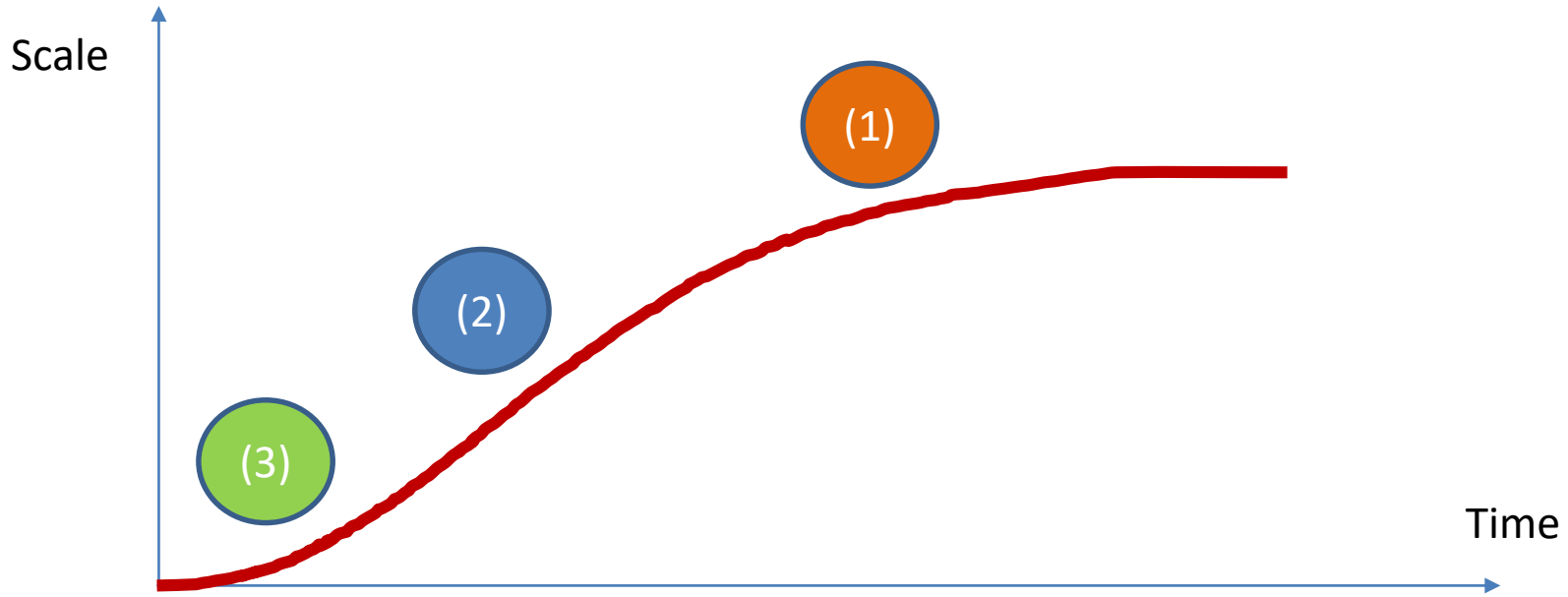
(*) through technological chains from production to end-use of each fossil fuel (coal, petroleum products, gas) in each energy/non-energy use of energy resources

Three global gas revolutions – today at different stages of corresponding waves

(1) US "Shale Revolution" & its global "domino effects" – we are facing its consequences

(2) Global "LNG Revolution" and its global "domino effects" – in the making

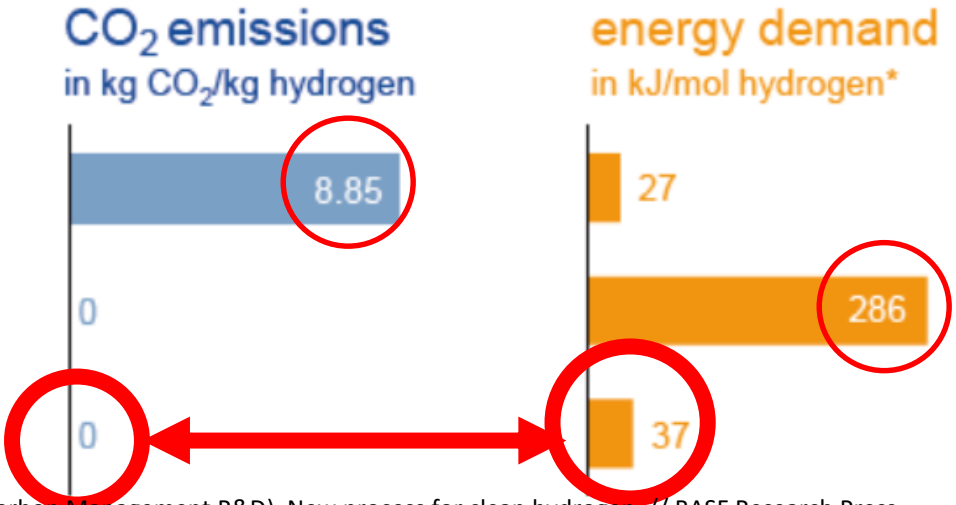
(3) Global "Green Revolution" – ongoing (in the infancy) – its global domino effects yet to be seen but can be predicted



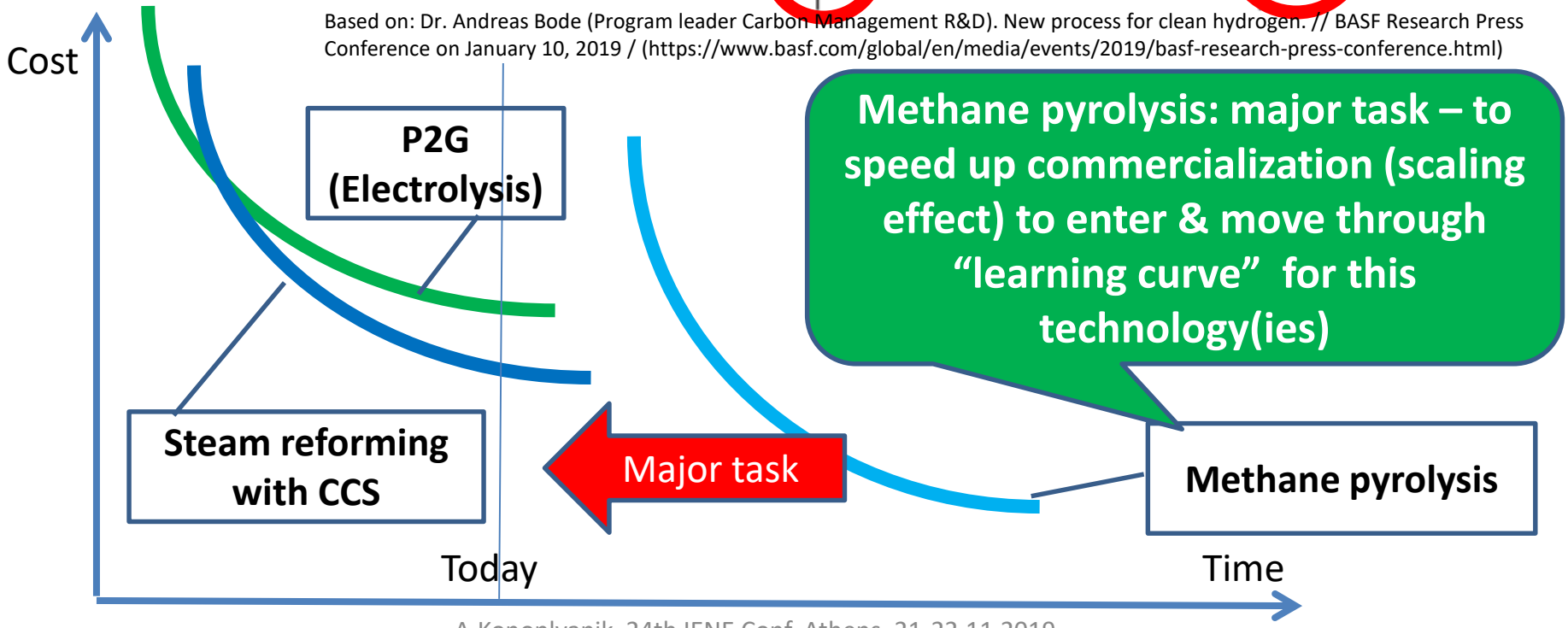
All other conditions being equal, & under technologically neutral regulation, methane pyrolysis might win competition in hydrogen production with two other key technologies

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	$CH_4 \rightarrow 2H_2 + C$



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)



Methane pyrolysis: major task – to speed up commercialization (scaling effect) to enter & move through "learning curve" for this technology(ies)

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

Global consequences of three gas (energy) revolutions

- **Transition from perception of "peak supply" to perception of "peak demand"** (*two revolutions*) =>
  - Compressing (in absolute and/or relative terms) markets for conventional energies, plus
  - Formation of new markets for conventional and/or unconventional energies =>
  - Additional increase of competition at the (traditional) energy markets plus competition for conquering the new markets =>
  - deviation of some key players from earlier agreed international law rules and principles for investment and trade ('dirty pool'?)
- **Decarbonization (transition to low-carbon development)** (*third revolution*)
  - Additional limitation or new opportunities?
  - Lessons from the past (GDP energy intensity in monetary terms: 1970-ies & beyond) for today and tomorrow (GDP carbon intensity) => advanced (preemptive) OR pursuit (post-factum) reaction?

Adaptation (incl. advanced) to the challenges of three revolutions: Russia's prospects in gas sphere

- **Zone of traditional possibilities**
  - Diversification of supplies (routes) to old and new markets
- **Zone of new possibilities**
  - Diversification of spheres of gas use (economic & ecological motivation)
  - Wholesale & retail markets (different entry mechanisms – no "gas-to-gas" competition => ssLNG vs pipe/lsLNG gas)
  - Gas for EU decarbonization (gas as feedstock for hydrogen production = new / additional segment for gas demand) – technological options:
    - PtG (electrolysis),
    - Steam reforming (with CO2 => with CCS => not "storage" but "sequestration")
    - Methane pyrolysis (& similar technologies): w/o CO2 & CCS => **economic priority for Russia & EU !?**
  - => from gas export – to export of gas & gas-decarbonization technologies
    - Gas export for production of H2 downstream Russia-EU gas value chain (where 80% of CO2 emissions)
    - H2-production technologies w/o CO2 emissions (if/when commercialized)
- **Zone of mutual benefits for Russian & EU** *(even w/o "domino effects")*
  - For EU: Cost decrease of EU decarbonization => increase of EU welfare with support of Russian gas & (jointly commercialized) technologies
  - For Russia: Expansion of demand for Russian gas in EU & for technologies of H2 production => additional monetization of natural resources of Russian gas
  - For both: "Win-win" scenario for Russia-EU in energy sphere (& not only in energy)

Disruptive Change

Easter Parade on Fifth Avenue, New York, 13 years apart

1900: where's the car?

1913: where's the horse?

Images: L. National Archive, www.archives.gov/research/american-cities/images/american-cities-101.jpg
R. sharpy.com/node/204.
Inspiration: Tony Seba's keynote lecture at AltCar, Santa Monica CA, 28 Oct 2014,
http://tonyseba.com/keynote-at-altcar-expo-100-electric-car-corporation-100-solar-by-2030/

Source: Campanale, Carobntracker

FEEM

Source: Prof. Dr. Manfred Hafner (*). Global Decarbonization: Challenges and Options. // Energetika XXI, Saint Petersburg, 14 November 2019 (*) Johns Hopkins University - School of Advanced International Studies (SAIS-Europe); SciencesPo - Paris School of International Affairs (PSIA); Fondazione Eni Enrico Mattei (FEEM)

Thank you for your attention!

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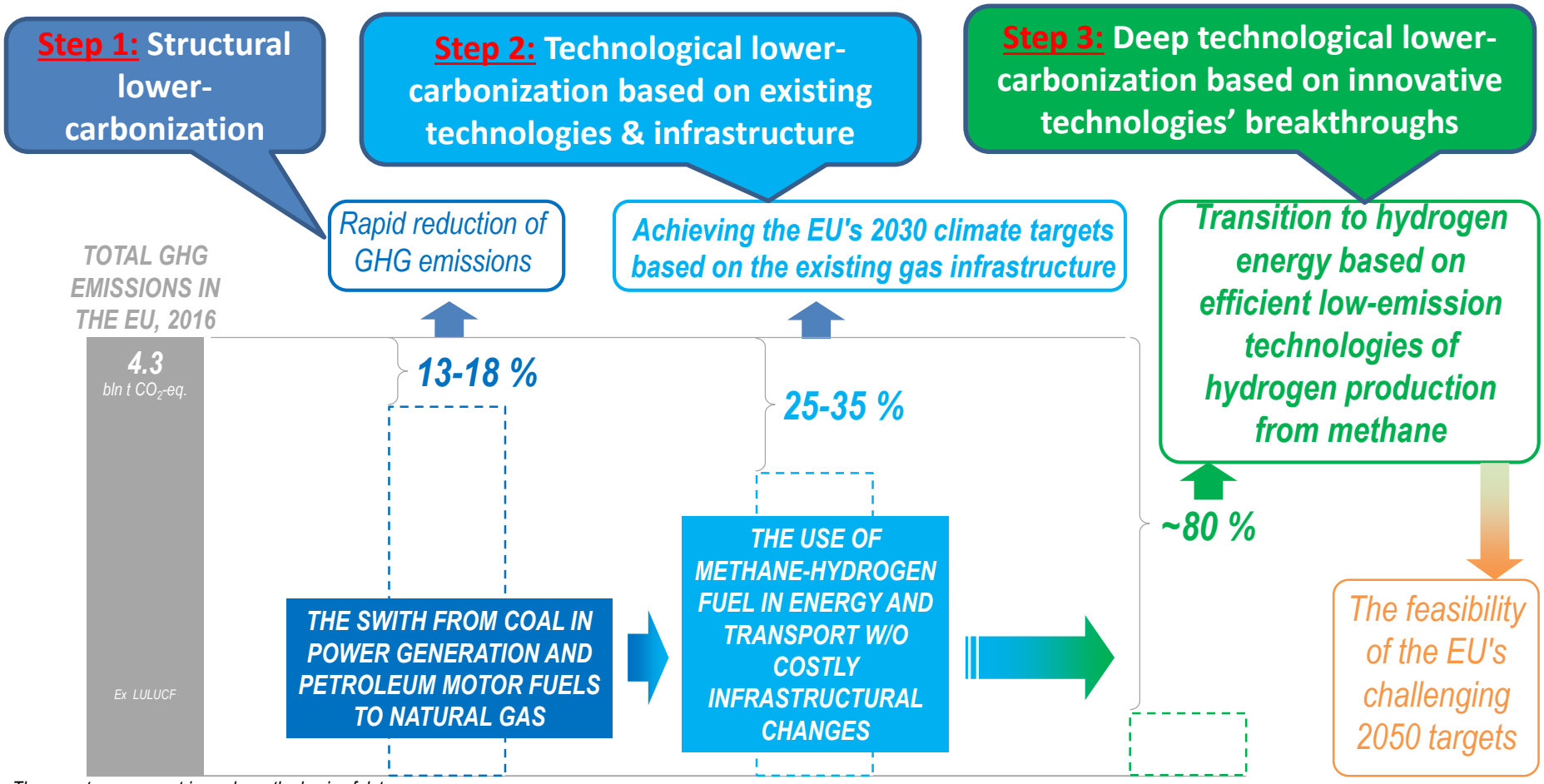
Back up slides

HOW to decarbonize: Gazprom's three-steps cooperative vision



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 cooperate & implement these three-steps vision ?

Cumulative effect of step' 1 measures

Cumulative effect of step's 1+2 measures

Cumulative effect of step's 1+2+3 measures

Step 1 cooperative measures

Step 2 cooperative measures

Step 3 cooperative measures

Substitution:
(1) Coal by gas in heat & electricity production,
(2) Petroleum products by gas in transport by:
- Compressed gas,
- LNG

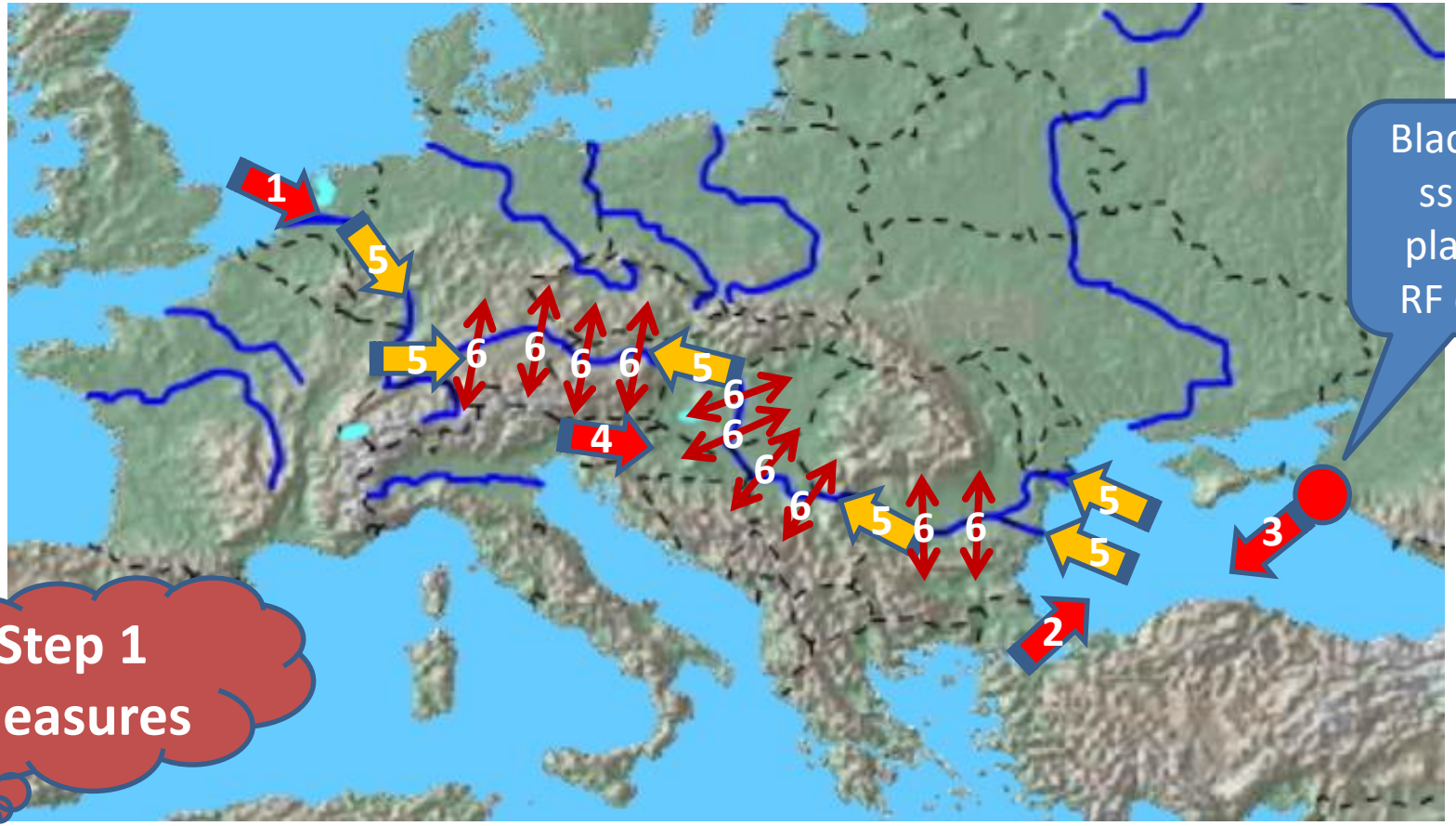
Methane-hydrogen mix (MHM) as fuel gas for compressor stations (CS) at pipelines, both in RF & EU, based on H2 production technologies at CS on-site without CO2 emission

H2 production without CO2 emission (based on Russian, EU &/or on jointly developed under RF-EU cooperation technologies) as its cost-competitive advantage compared to PTG/electrolysis (too much energy intensive & thus too costly) and/or Steam Reforming with obligatory CCS (CCS as incremental immanent cost component up to 30+%)

Small-scale LNG for Black Sea & Danube region

Potential incremental export of Rus gas for H2 production & of H2 production technologies (either of Rus origin or jointly developed by RF & EU)

Prospects of creation of Black Sea-Danube/CSEE ssLNG market

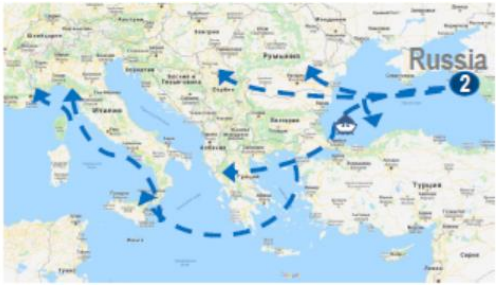


1-4 = ssLNG supplies to SEE (1 = from NS area by barges; 2 = through Turkish Straits (limited); 3 = from Black Sea RF plant by sea-river vessels; 4 = by trucks via N.Italy); 5 = supplies within Rheine-Danube waterway by barges/see-river vessels; 6 = ssLNG fueling stations

Black sea plant

Location	Black sea coast of Russia
Capacity	0.5 – 1.5 mtpa
Status	Prefeasibility study
Delivery countries	Countries of South-Eastern Europe, countries of Danube river region, Turkey.

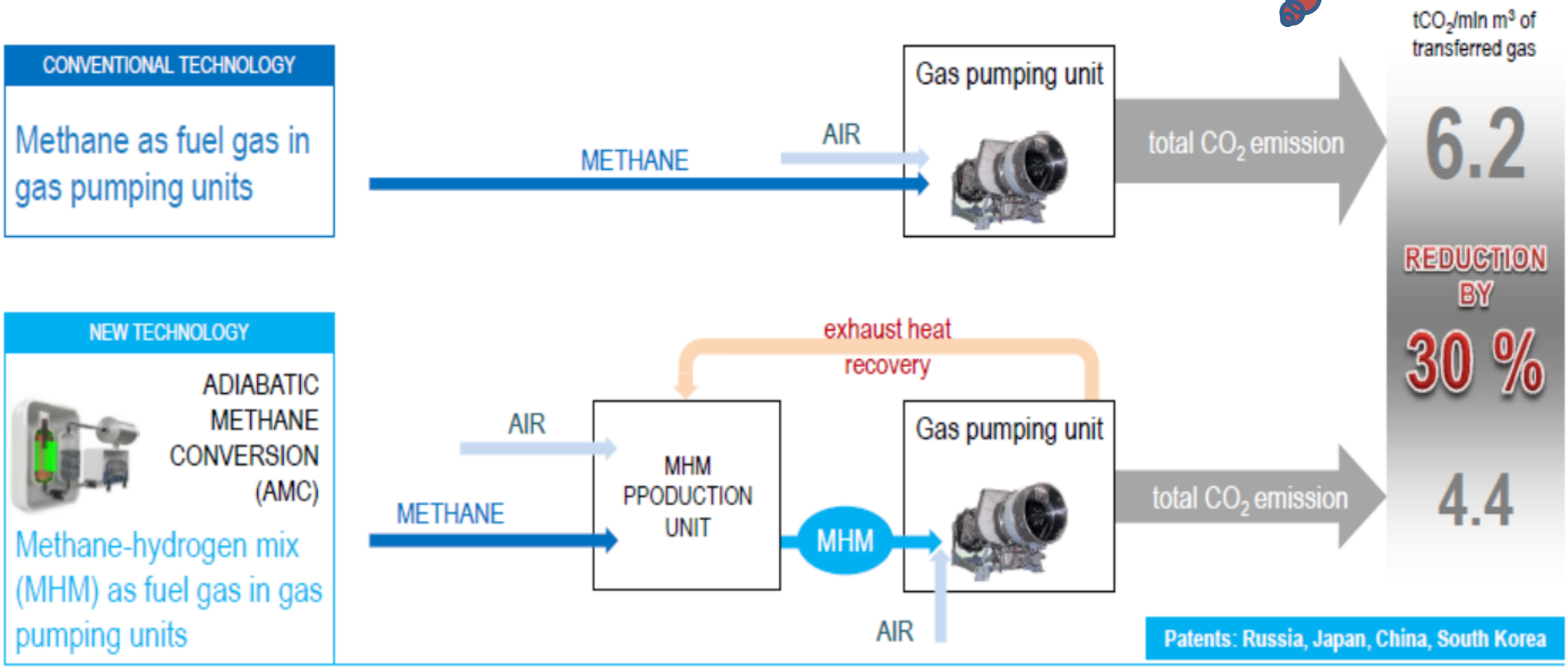
– potential bunkering areas



Source: K.Neuymin (Gazprom). Development of Small and Medium –Scale LNG Infrastructure in Russia. Presentation at 9th SPB International Gas Forum, 1-4.10.2019

ADIABATIC METHANE CONVERSION

Step 2 Measures



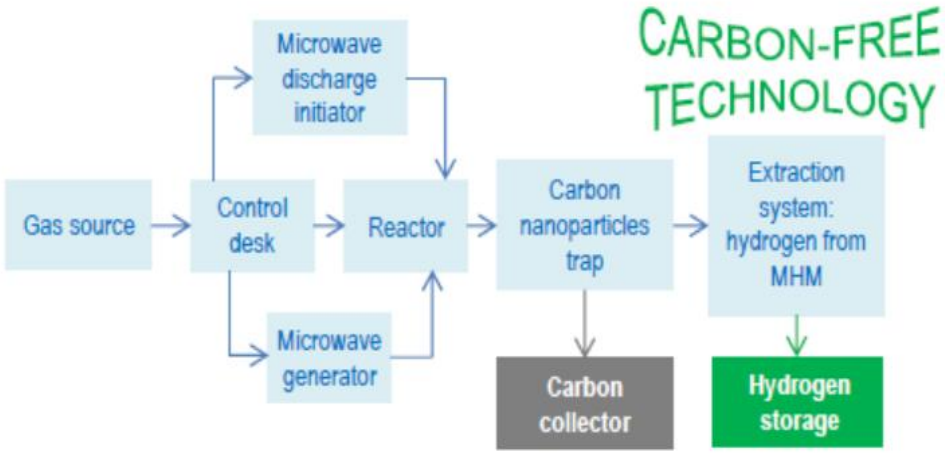
Expert review by the Center for Integrated Development of Technologies and Energy Technology Systems (KORTES Center LLC), Gazprom-Geotekhnologii LLC

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

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)