

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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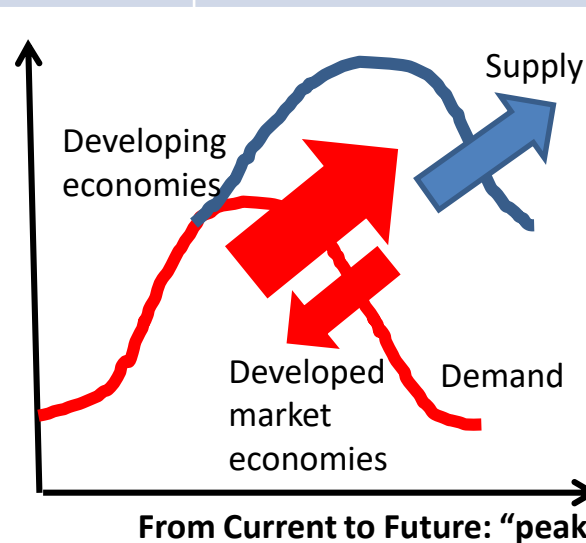
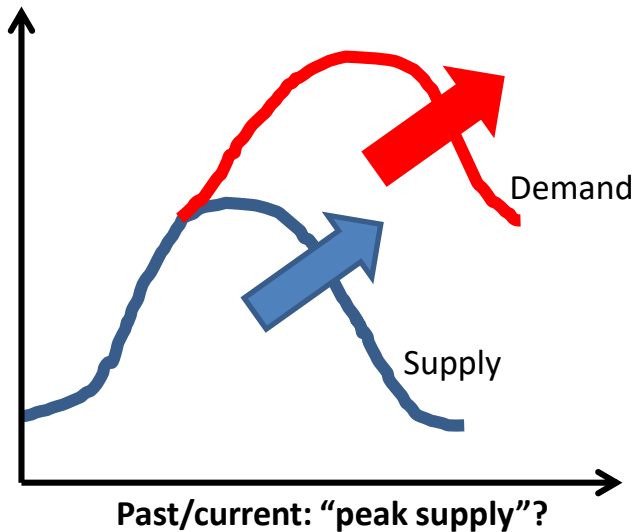
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World Energy: The Change of Paradigm?

Supply	Demand
<ul style="list-style-type: none"> - Hubbert's peak (curve) - Hotelling's rent (theorem) - Chevalier's turning point - STP (resource rent, economy of scale) 	<ul style="list-style-type: none"> - Economic growth (industrial-type): industrialization, centralization, concentration - Population growth

Supply	Demand
<ul style="list-style-type: none"> - STP progress, incl. US shale revolution (from resource rent under economy of scale to technological rent) => Hotelling anti-theorem 	<ul style="list-style-type: none"> - 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



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

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

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?***

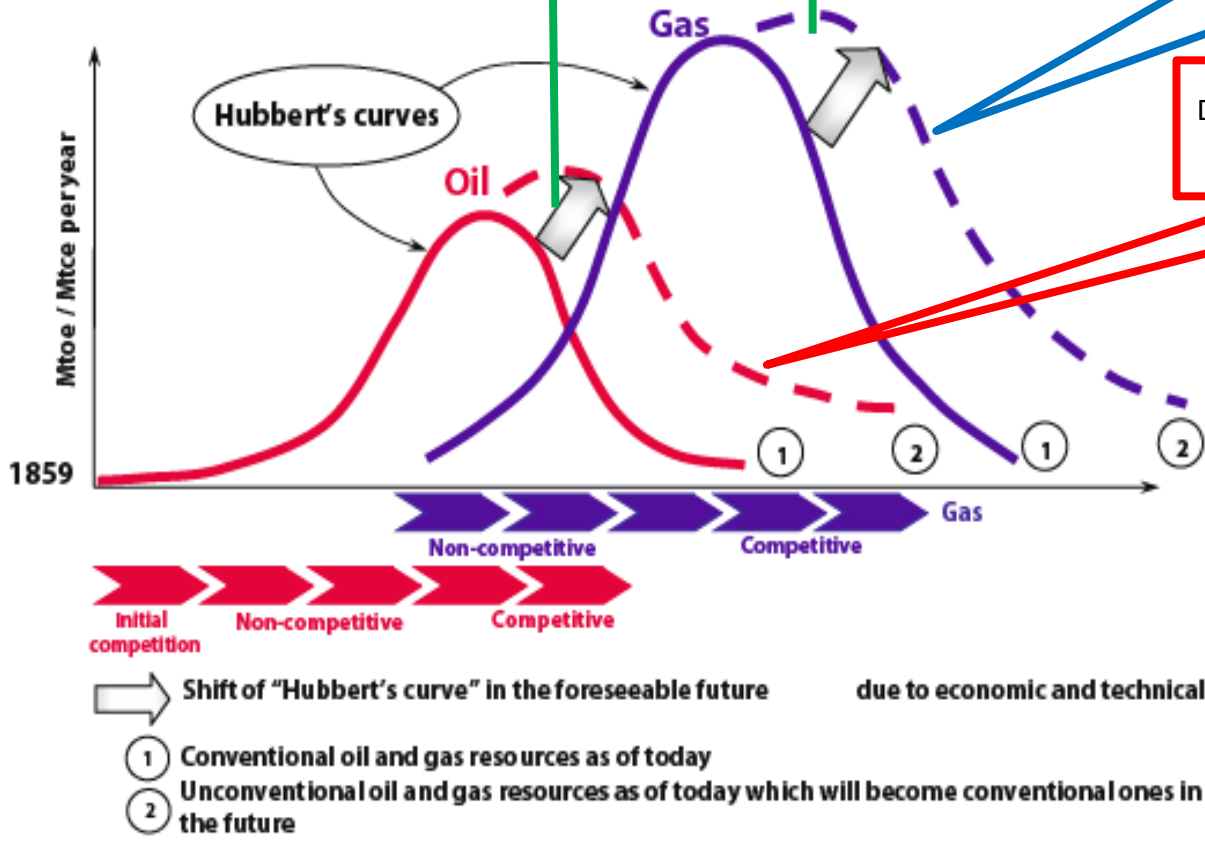
⇒ Russia has its competitive niche which allows this country to monetize its vast non-renewable energy resource (incl. most clean – natural gas), but on the new technological basis => Hydrogen as one of the solutions

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]

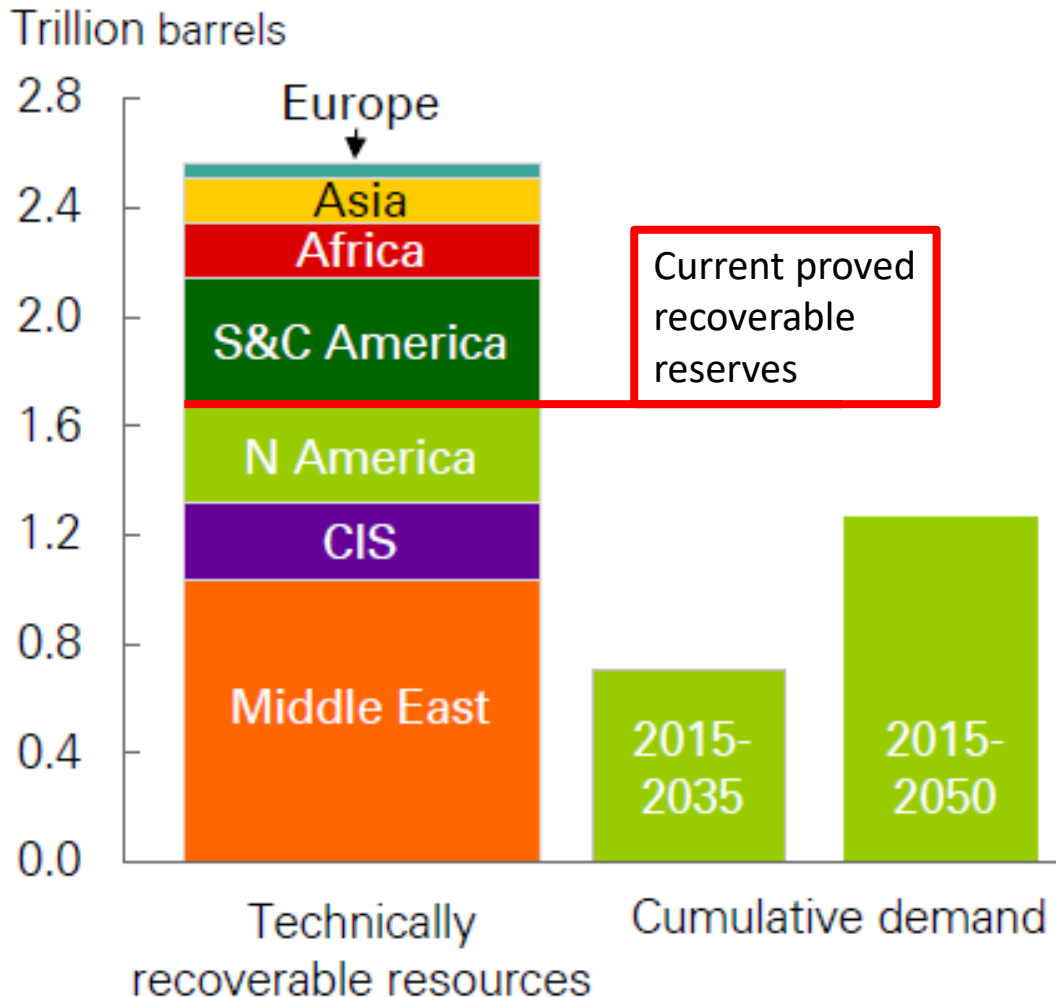
(*) later reproduced in "Putting a Price on Energy..." (ECS, 2007, p.53) [4], where this particular basic picture is taken from

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)

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

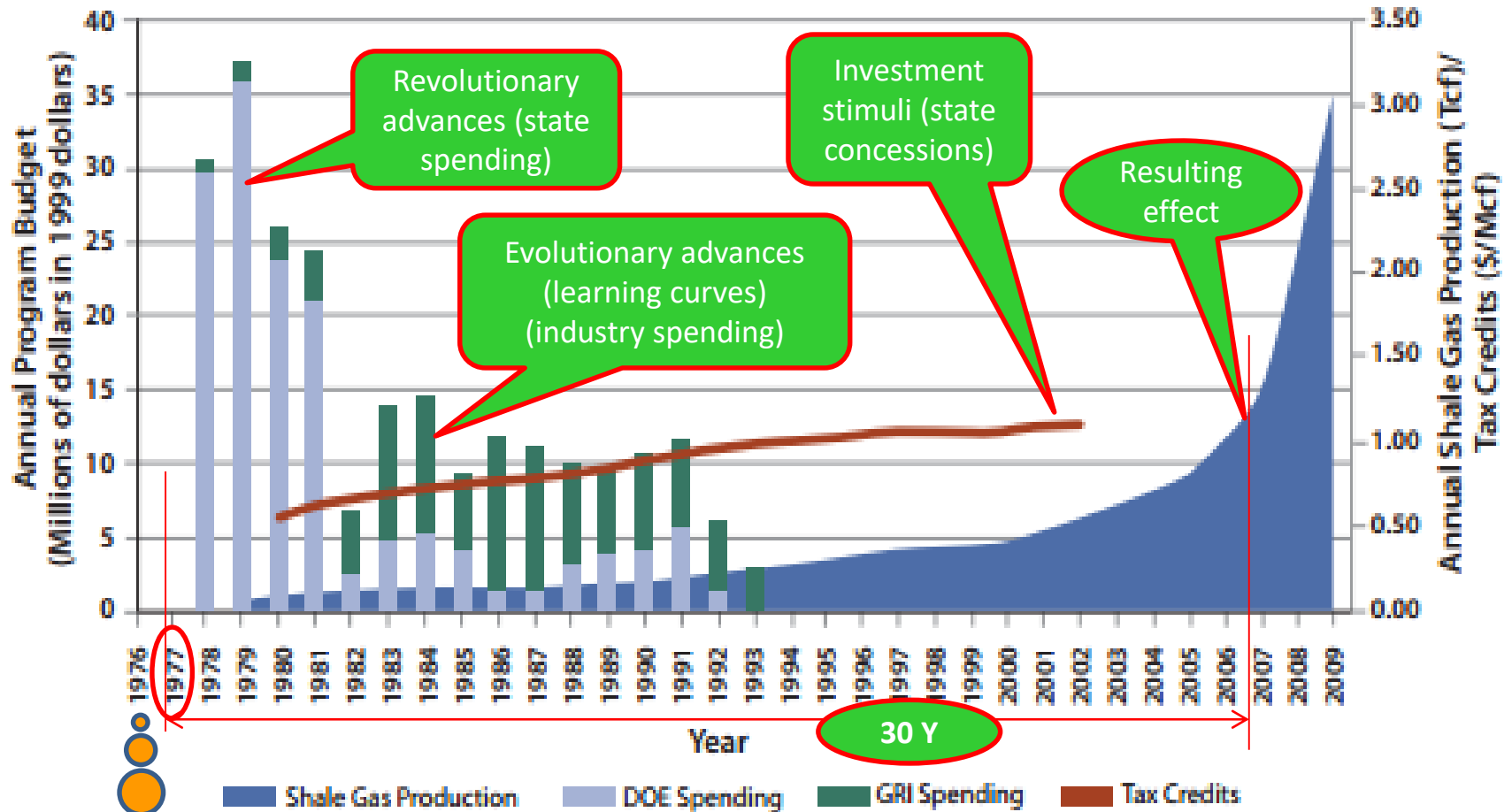
Estimates of technically recoverable resources and cumulative oil demand



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-E017-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

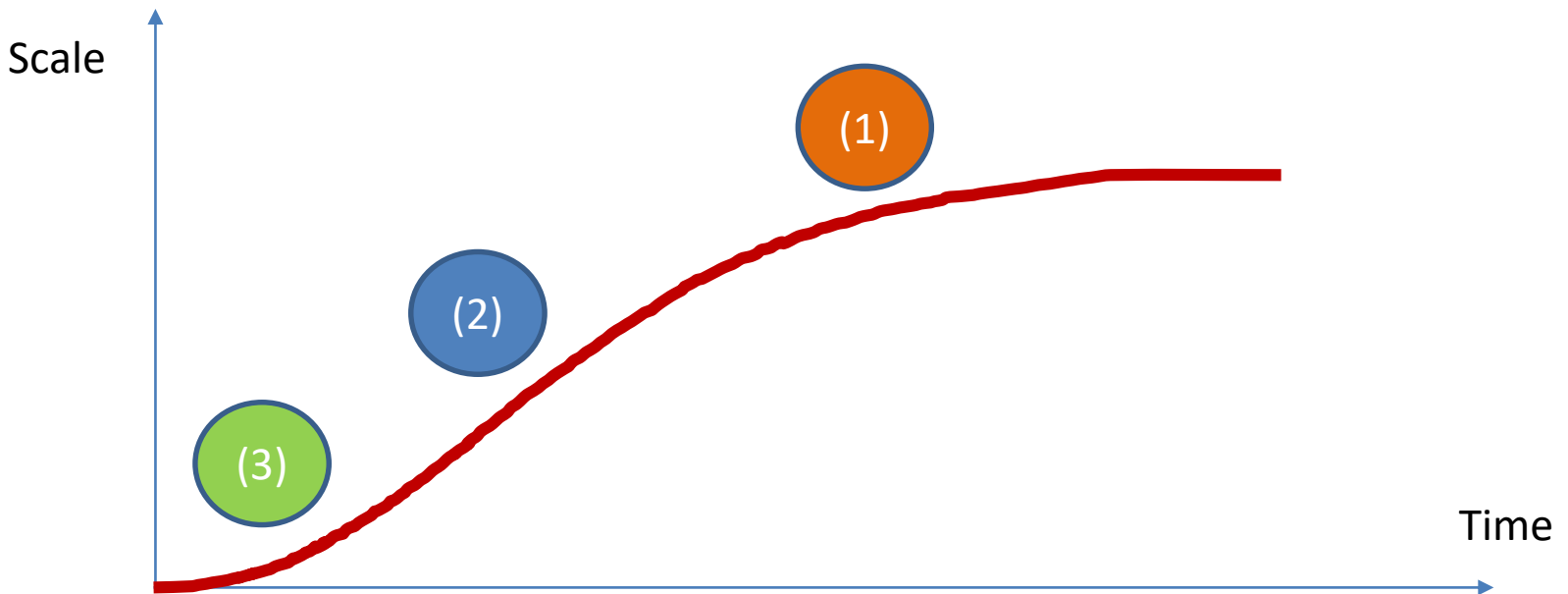
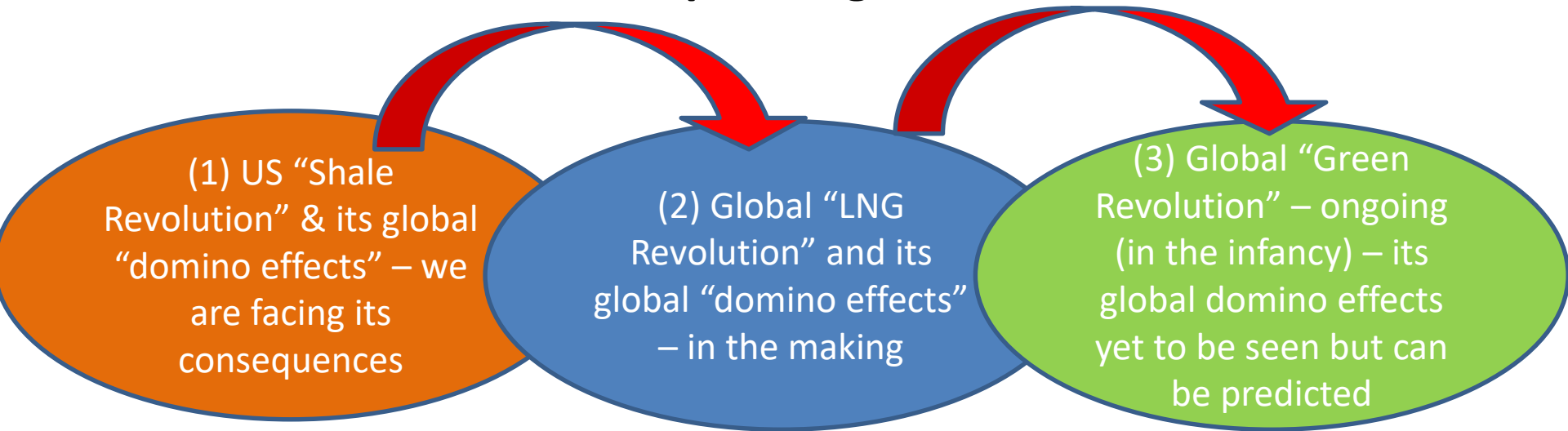
Source of the basic Figure: Figure 8.1 "CBM RD&D Spending & Supporting Policy Mechanisms" from The Future of Natural Gas. An Interdisciplinary MIT Study, 2011, p.163; [44] Figure adapted by this author, first presented in: A.Konoplyanik. "The US Shale Gas Revolution And Its Economic Impacts In The Non-US 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

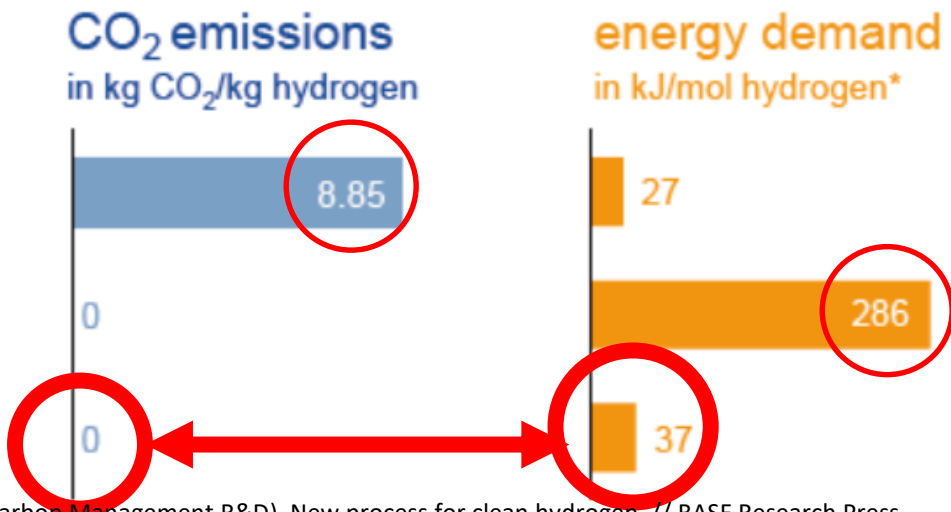
Three global gas revolutions – today at different stages of corresponding waves



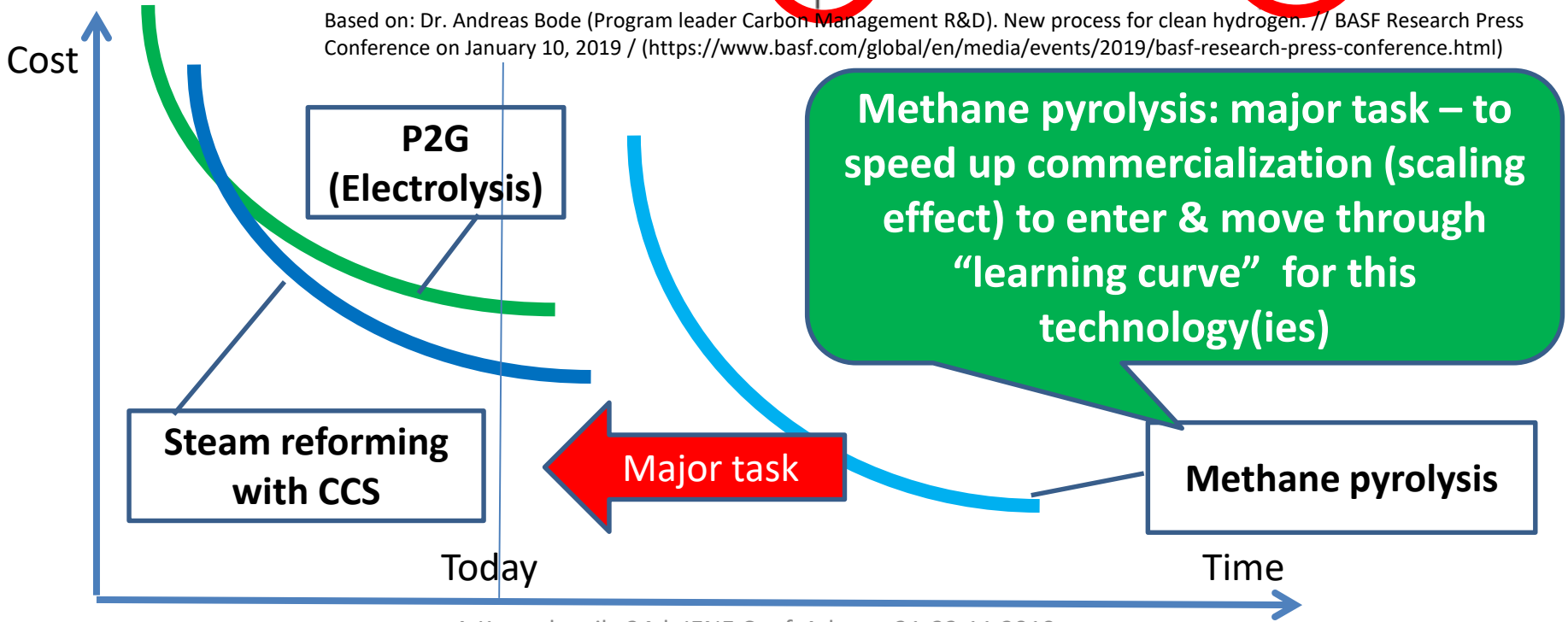
All other conditions being equal, & under technologically neutral regulation, methane pyrolysis might win competition in hydrogen production with two other key technologies

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







Steam reforming of natural gas	$\text{CH}_4 + 2\text{H}_2\text{O} \rightarrow 4\text{H}_2 + \text{CO}_2$
Water electrolysis	$2\text{H}_2\text{O} \rightarrow 2\text{H}_2 + \text{O}_2$
Methane pyrolysis	$\text{CH}_4 \rightarrow 2\text{H}_2 + \text{C}$



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>)



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/mazes/american-cities-101.jpg
R. sharpys.com/node/204

Inspiration: Tom Sebe's keynote lecture at AltCar, Santa Monica CA, 28 Oct 2014,
<http://tomsebe.com/wordpress/wp-content/uploads/2014/10/altcar-transportation-100-solas-by-2030/>

Source: Campanale, Carobntracker



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)

A.Konoplyanik, 24th IENE Conf, Athens, 21-22.11.2019

Thank you for your attention!

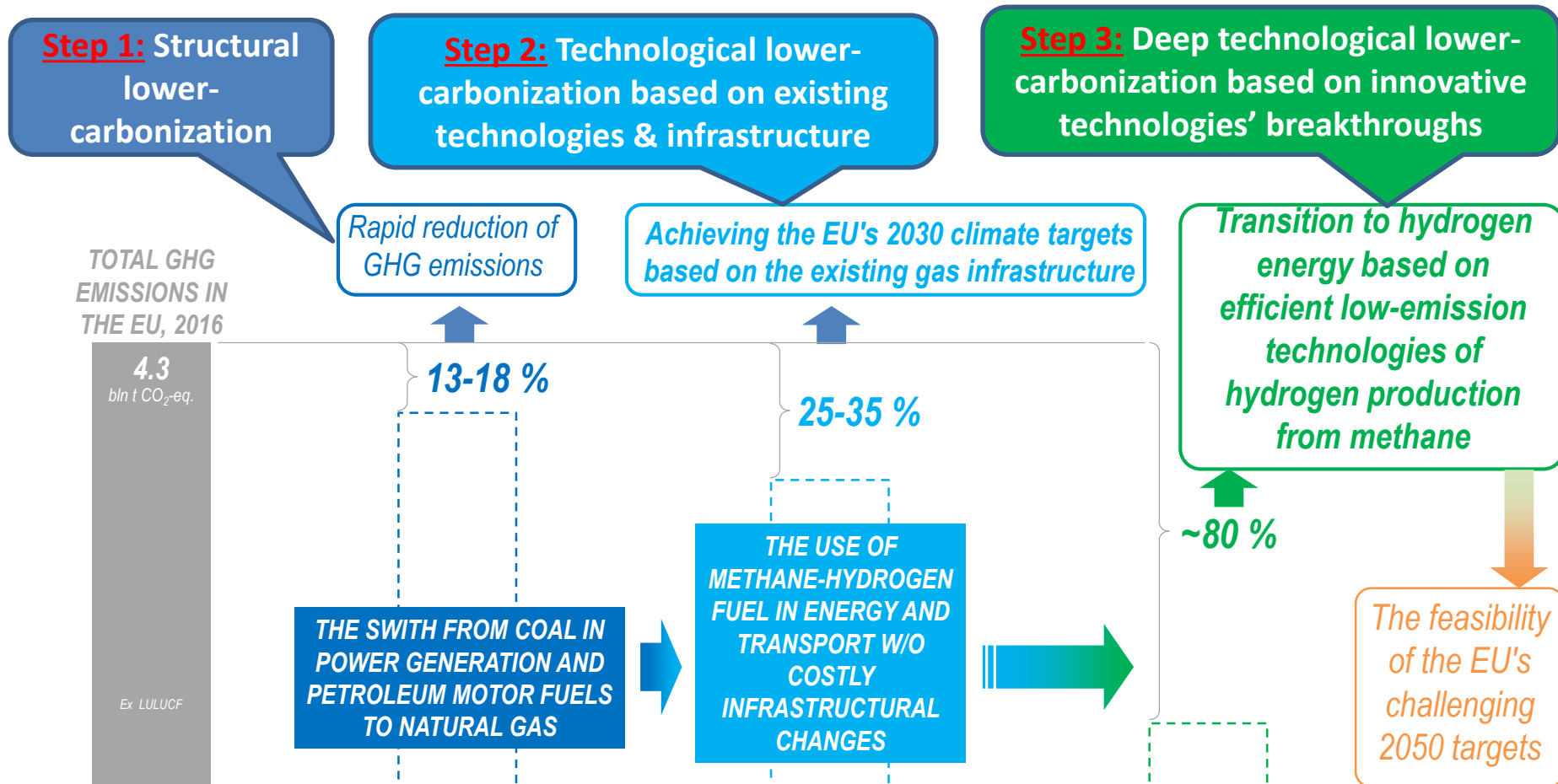
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Back up slides

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

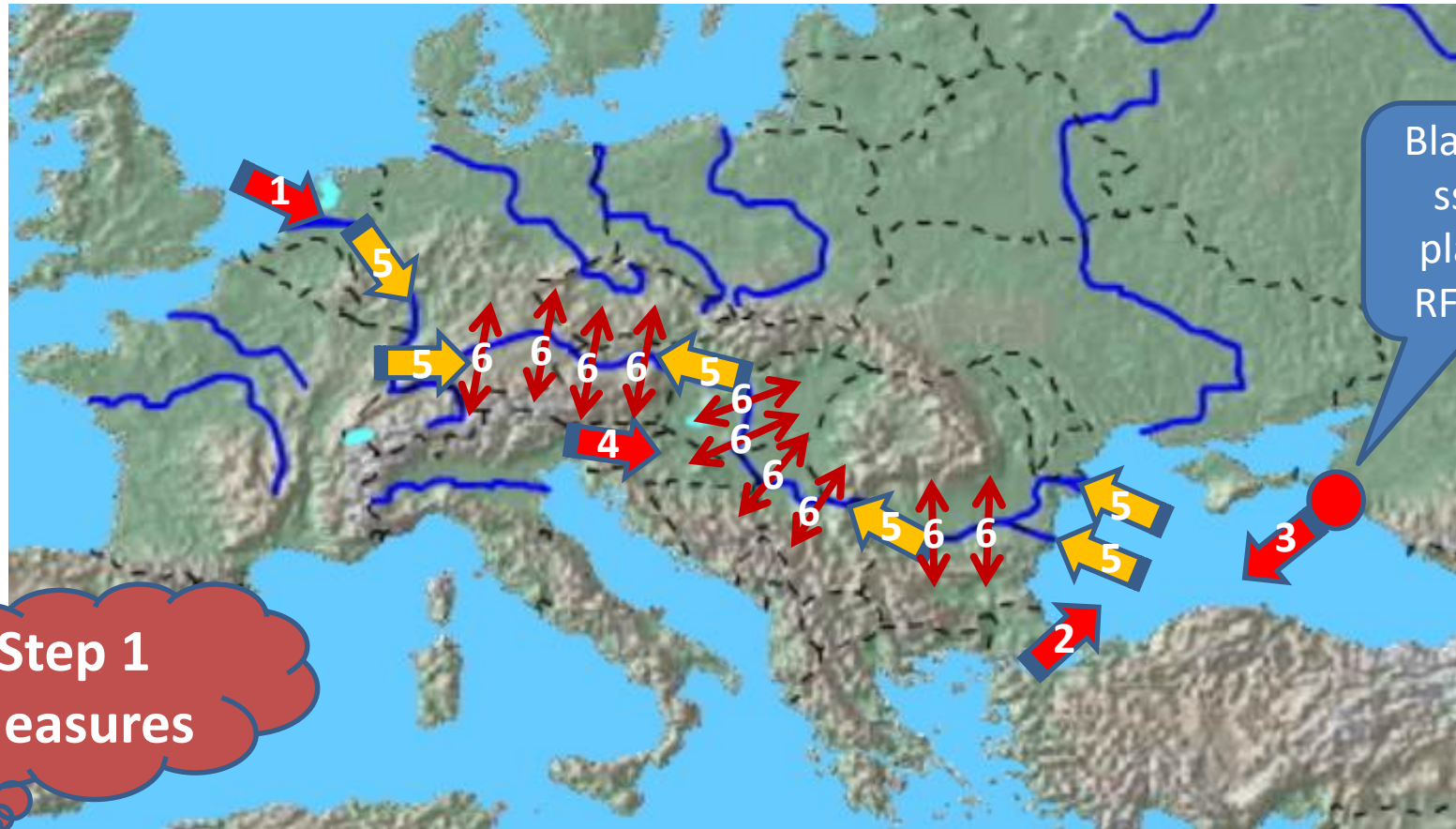
Methane-hydrogen mix (MHM) as fuel gas for compressor stations (CS) at pipelines, both in RF & EU, based on H2 production technologies at CS on-site without CO2 emission

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.

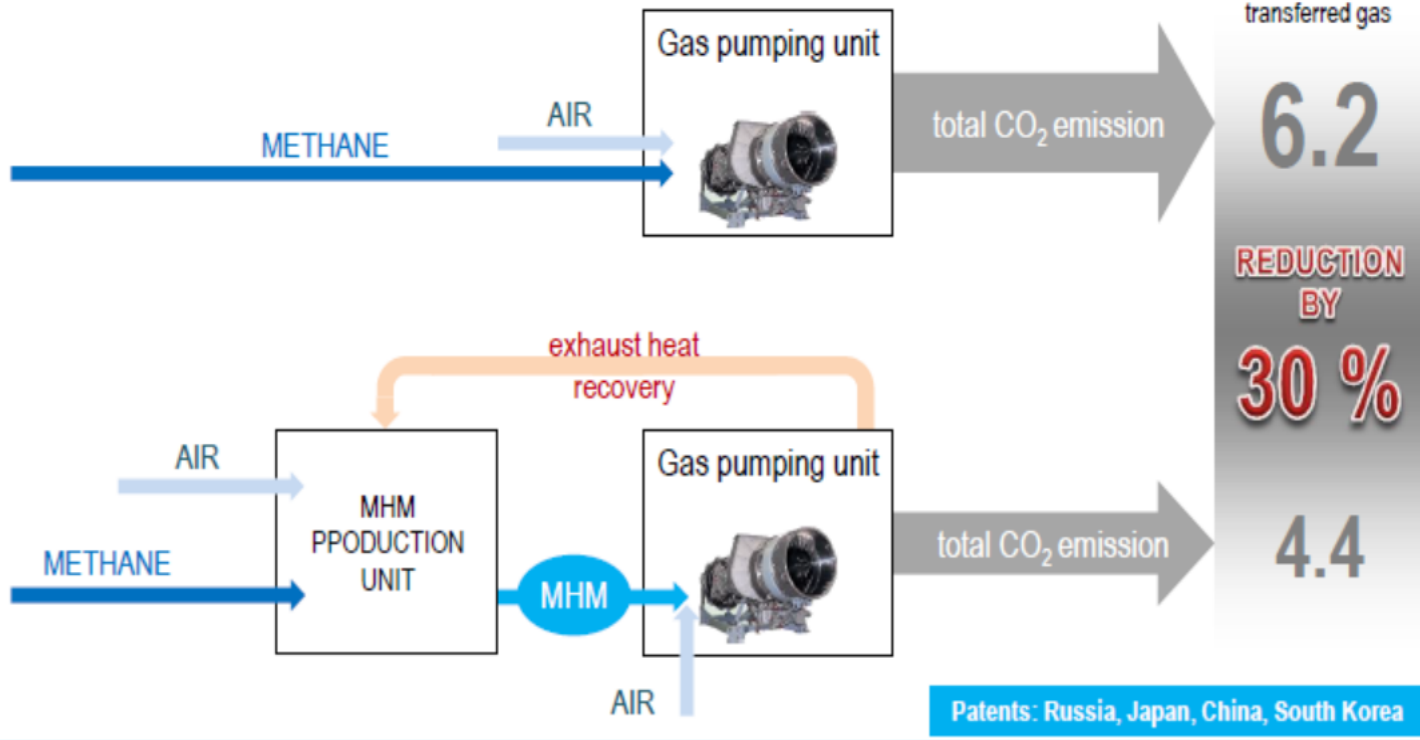
- potential bunkering areas



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

CONVENTIONAL TECHNOLOGY

Methane as fuel gas in gas pumping units



NEW TECHNOLOGY

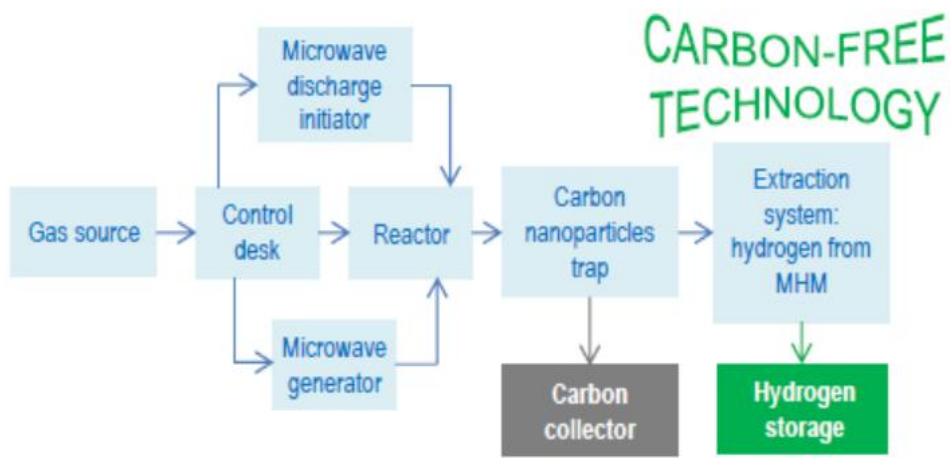
ADIABATIC METHANE CONVERSION (AMC)

Methane-hydrogen mix (MHM) as fuel gas in gas pumping units

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)

Step 3 Measures

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



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

PROTOTYPE PLANT CARBON MATERIAL



CAPACITY OF:

- hydrogen – up to 1 m³/h;
- carbon material – up to 80 g/h