Prospects of Russia-EU cooperation in gas-based hydrogen energy economy as a competitive alternative to the pre-determined EU "green hydrogen" solution

Prof. Dr. A.A.Konoplyanik,

Adviser to Director General, Gazprom export LLC;
Co-chair of Work Stream 2 "Internal Markets", Russia-EU Gas Advisory Council;
Member of Scientific Council on System Research in Energy, Russian Academy of Sciences

Presentation at the Gazprom Business Club meeting, 16.09.2021, online

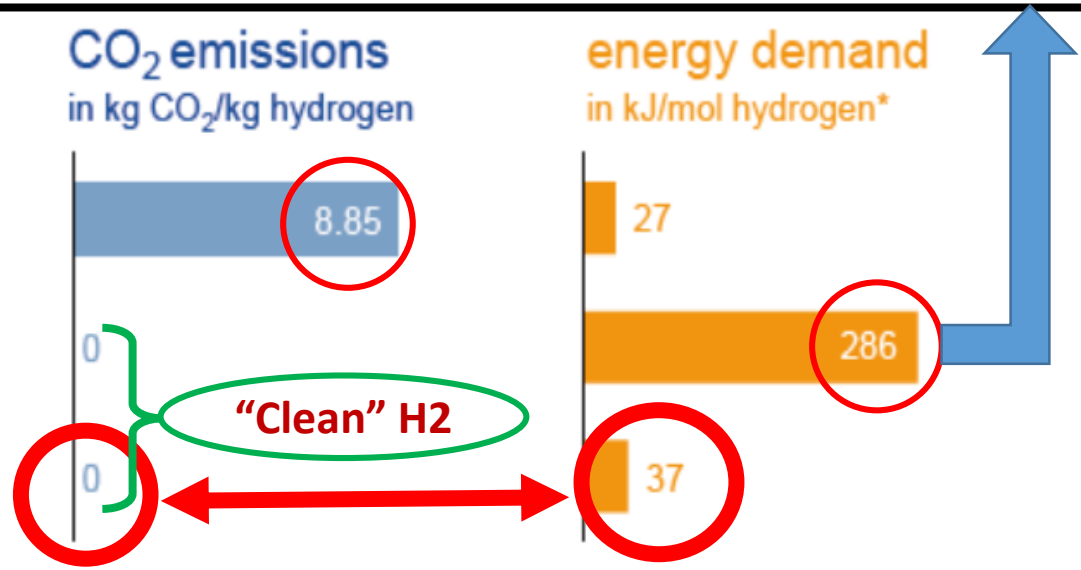
Disclaimer: Views expressed in this presentation do not necessarily reflect (may/should reflect) and/or coincide (may/should be consistent) with official position of Gazprom Group (incl. Gazprom JSC and/or Gazprom export LLC), its stockholders and/or its/their affiliated persons, or any Russian official authority, and **are within full personal responsibility of the author of this presentation.**

All other conditions being equal, methane pyrolysis (& similar technologies) have clear competitive advantages against two other key technologies in hydrogen production (MSR+CCS & electrolysis) under technologically neutral regulation

CC(U)S is needed!!! => additional imputed costs (CAPEX + OPEX) => add. 20/30+% (*) (CEC: twice as high (*)) => additional element of cost budget => WORSENS financeability

Vision to diminish high-cost energy density – to use excessive RES electricity at zero or negative prices => this leads to unstable (regularly interrupted by natural reasons) RES-based H2 production cycle => prolongation of pay-back periods (of debt-financed CAPEX) => WORSENS financeability

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	$CH_4 \rightarrow 2H_2 + C$



Source: A.Konoplyanik 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)

(1) No need in CC(U)S => CAPEX/OPES saving
(2) Marketing of carbon black = additional element of revenue budget => start of new investment cycle(s) based on carbon black
(3) In case of storage, carbon black does not provide same negative effects as CO2 => IMPROVES financeability

(*) René Schutte, N.V. Nederlandse Gasunie. Production of Hydrogen. // Masterclass in Hydrogen, Skolkovo – Energy Delta Institute, Moscow, May 23, 2019 (https://drive.google.com/open?id=1g_4TiiKAKGaJziXG8TWjTdpncfipj9x1)
(**) Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the regions. A hydrogen strategy for a climate-neutral Europe // EUROPEAN COMMISSION, Brussels, 8.7.2020, COM(2020) 301 final, p.4-5, footnote 26 (https://ec.europa.eu/energy/sites/ener/files/hydrogen_strategy.pdf)

What is clean energy? Depends on how you calculate/consider it...

Wrong perceptions as if renewable H2 is the only clean H2 and, moreover, that it is clean at all

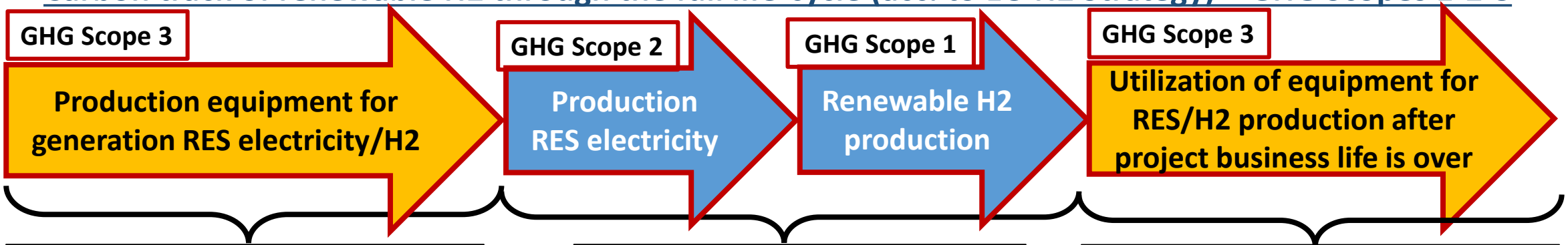
A hydrogen strategy for a climate-neutral Europe (Brussels, 8.7.2020 COM(2020) 301 final):

'**Renewable hydrogen**' is hydrogen produced through the electrolysis of water (in an electrolyser, powered by electricity), and with the electricity stemming from renewable sources. The **full life-cycle greenhouse gas emissions of the production of renewable hydrogen are close to zero <…> 'Clean hydrogen'** refers to renewable hydrogen.

Siemens/Gascade/Nowega (Hydrogen infrastructure – the pillar of energy transition…, 2020):

"If the electricity required for electrolysis comes exclusively from renewable, CO2-free sources, the **entire production process is completely CO2-free**."

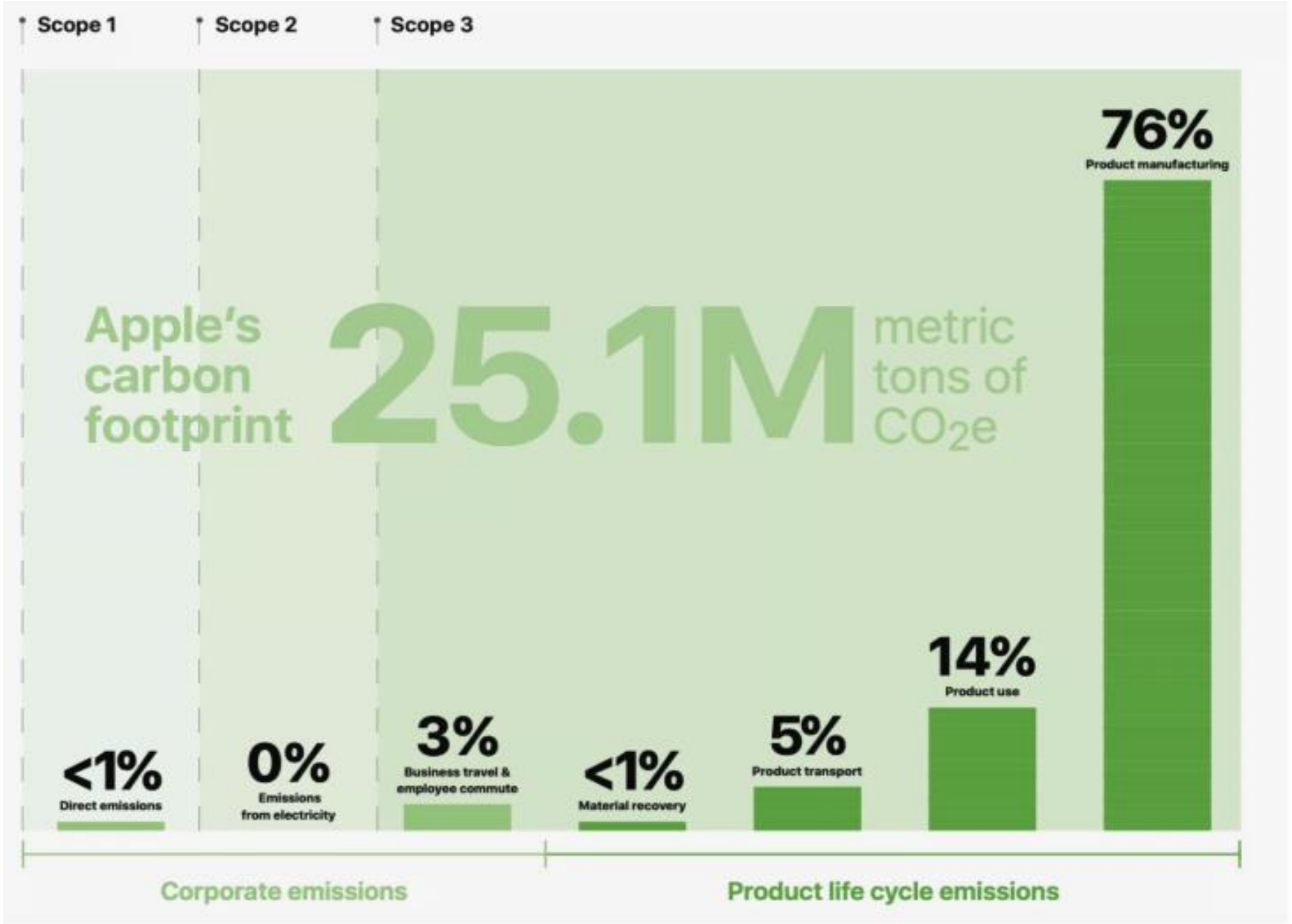
Carbon track of renewable H2 through the full life-cycle (acc. to EU H2 Strategy) – GHG Scopes 1-2-3



CO2 emissions: **NOT equal to Zero** EU H2 Strategy: **not included** Geographical location: **beyond EU**	CO2 emissions: equal to Zero EU H2 Strategy: included Geographical location: within EU	CO2 emissions: **NOT equal to Zero** EU H2 Strategy: **not included** Geographical location: **beyond EU**

Daniel Yergin, Pulitzer Prize winner for "The Prize" book at presentation of his new book "The New Map":
"**NEW SUPPLY CHAINS FOR NET-ZERO CARBON REQUIRES CARBON!!! … They require diesel to operate shuttle in mining**…"

(Source: A conversation with Pulitzer Prize winner and energy expert Daniel Yergin, Atlantic Council, 25.09.2020; https://www.youtube.com/watch?v=hWMOU8IjRhI)

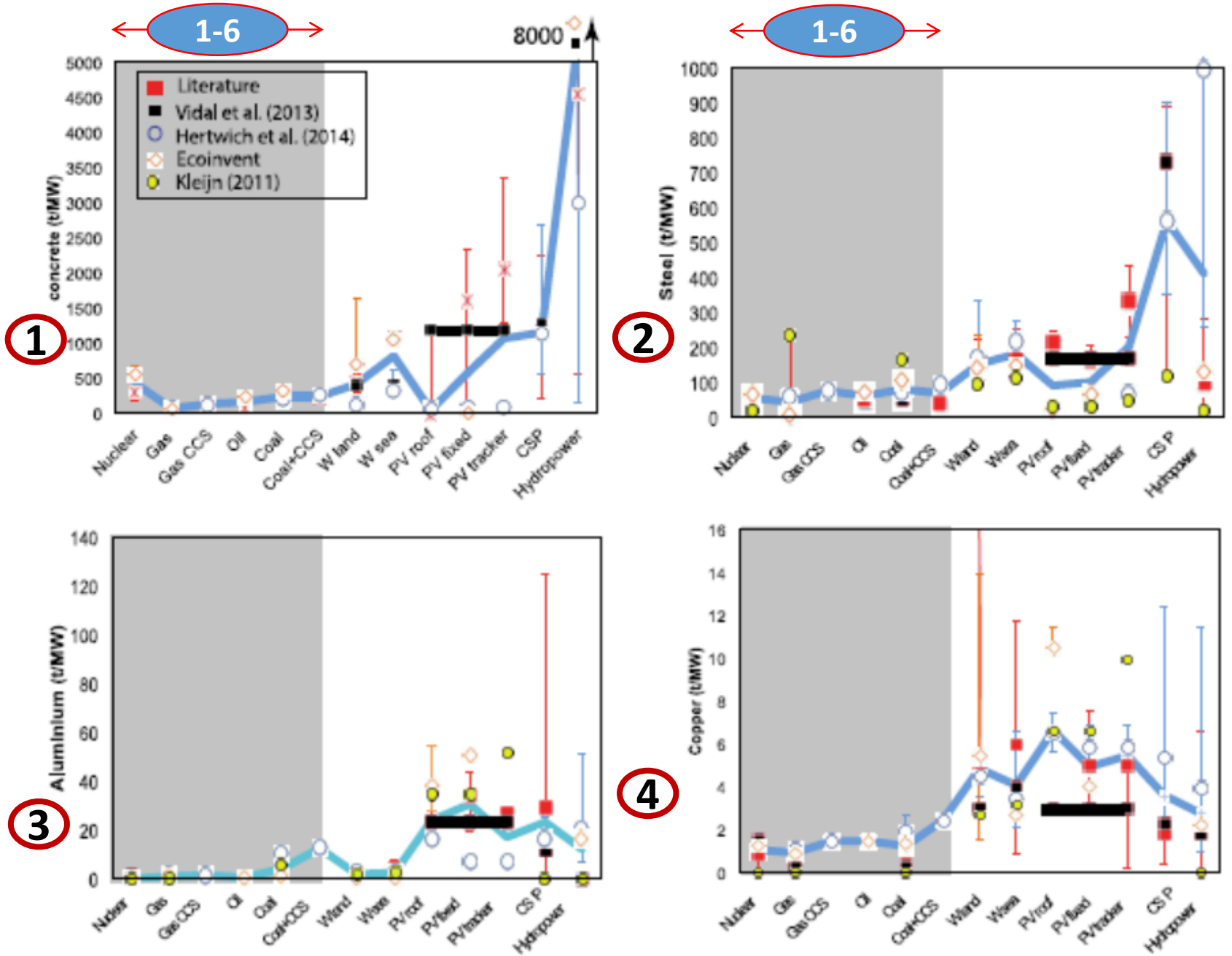


The importance of scope 3 emissions – Apple carbon footprint
Credit: Apple

Why it is important to consider GHG emissions within all THREE Scopes?

(Illustrative example from Apple which it has presented to the public voluntarily – direct analogy with "green" H2)

Source: What are Scopes 1, 2 and 3 of Carbon Emissions? // PlanA Academy, 12.08.2020 (https://plana.earth/academy/what-are-scope-1-2-3-emissions/)



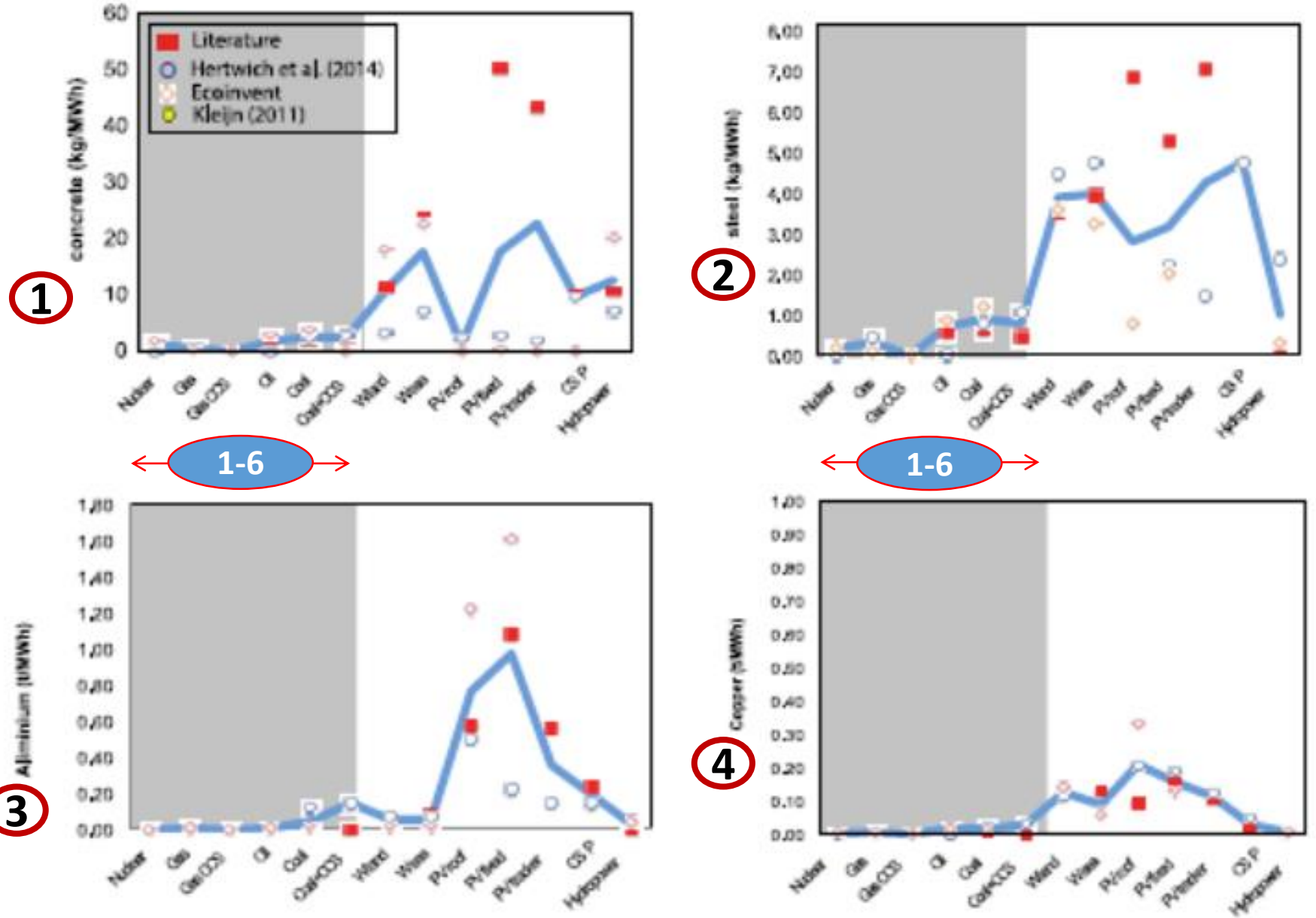
Quantities (t/MW) of four structural materials used to manufacture different power generation infrastructure (material intensity) :

1 – concrete,
2 – steel,
3 – aluminium,
4 – copper

(fossil fuel power generation technologies are in the gray shaded area;
colour version of the figure at: www.iste.co.uk/vidal/energy/zip)

Source: Olivier Vidal. Mineral Resources and Energy. Future Stakes in Energy Transition. // ISTE Press Ltd - Elsevier Ltd, UK-US, 2018, 156 pp. (Figure 5.2./p. 72)

From left to right: (1) Nuclear, (2) Gas, (3) Gas+CCS, (4) Oil, (5) Coal, (6) Coal+CCS, (7) Wind land, (8) Wind sea, (9) PV roof, (10) PV fixed, (11) PV tracker, (12) CSP, (13) Hydropower



Mass of material in kg required to produce 1 MWh electricity:

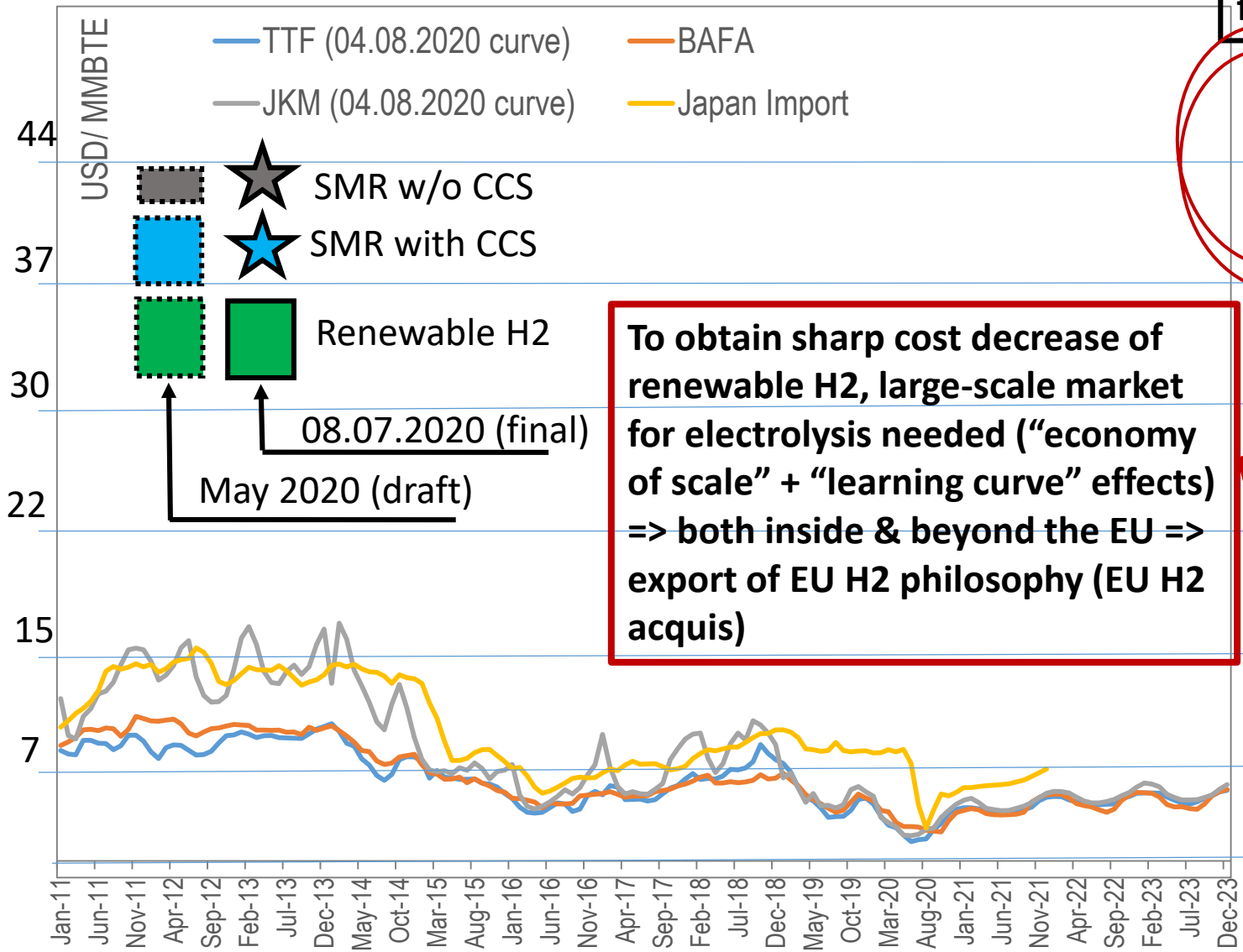
1 – concrete,
2 – steel,
3 – aluminium,
4 – copper

(calculated with the material intensities shown in Figure 5.2 and Table 5.1; the gray shaded area indicates fossil fuel-based electricity production; colour version of the picture at: www.iste.co.uk/vidal/energy.zip)

Source: Olivier Vidal. Mineral Resources and Energy. Future Stakes in Energy Transition. // ISTE Press Ltd - Elsevier Ltd, UK-US, 2018, 156 pp. (Figure 5.3./p. 74)

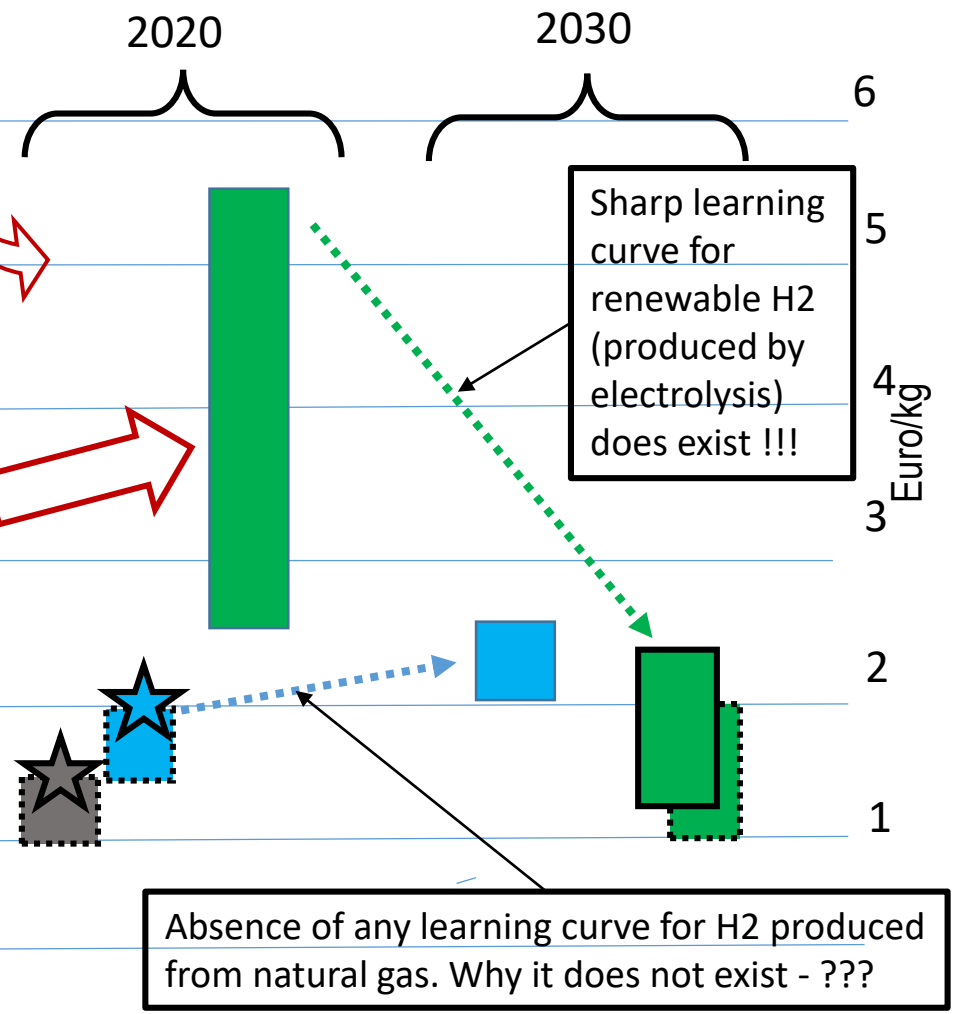
From left to right: (1) Nuclear, (2) Gas, (3) Gas+CCS, (4) Oil, (5) Coal, (6) Coal+CCS, (7) Wind land, (8) Wind sea, (9) PV roof, (10) PV fixed, (11) PV tracker, (12) CSP, (13) Hydropower

European Commission's estimated costs of H2 production by the key technologies (as presented in the EU Hydrogen Strategy as of 08.08.2020) – and natural gas prices



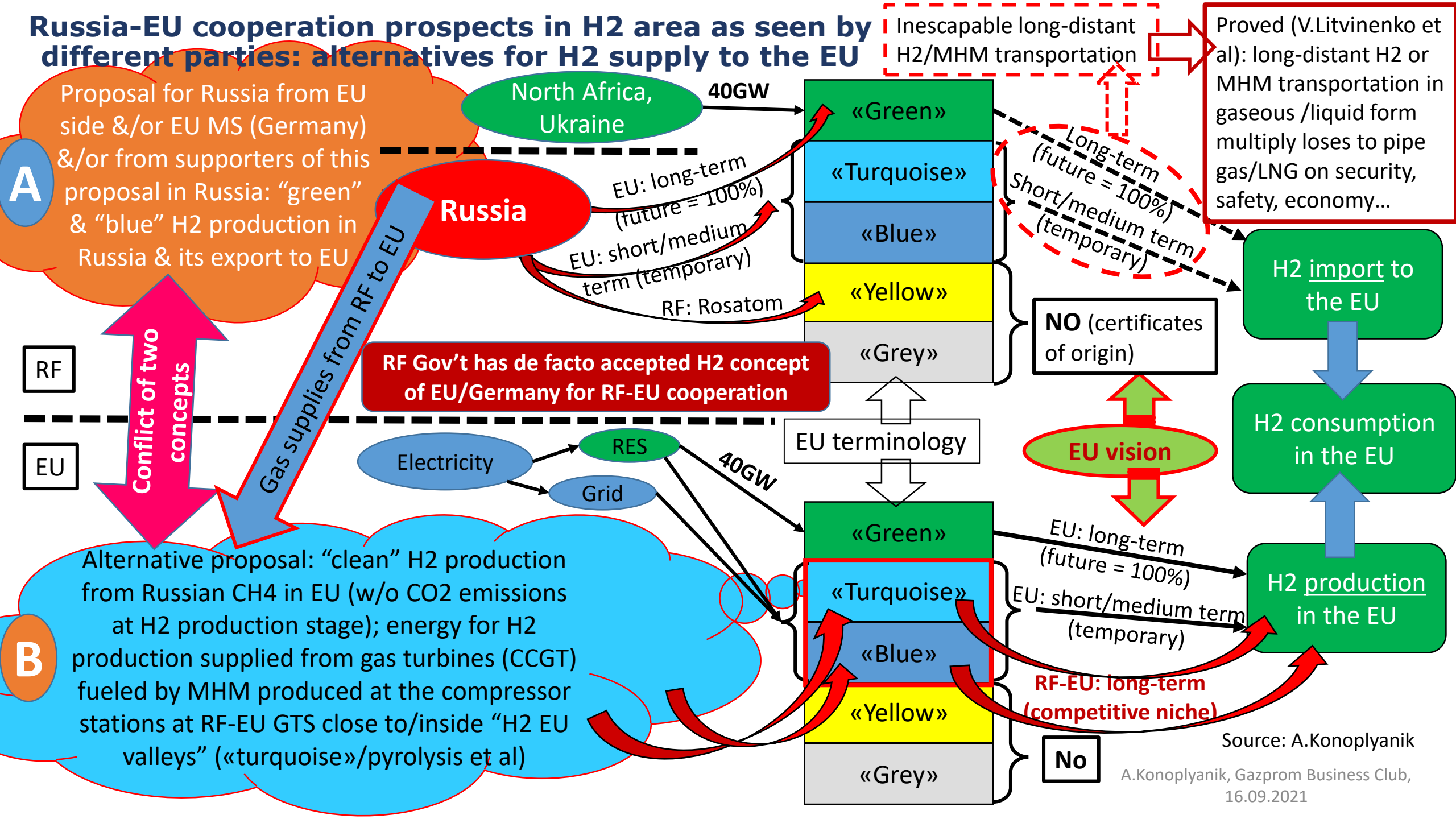
To obtain sharp cost decrease of renewable H2, large-scale market for electrolysis needed ("economy of scale" + "learning curve" effects) => both inside & beyond the EU => export of EU H2 philosophy (EU H2 acquis)

Wright's Law: each doubling of production volumes diminishes unit costs by 28% => demand for multiple increase of electrolyzers production



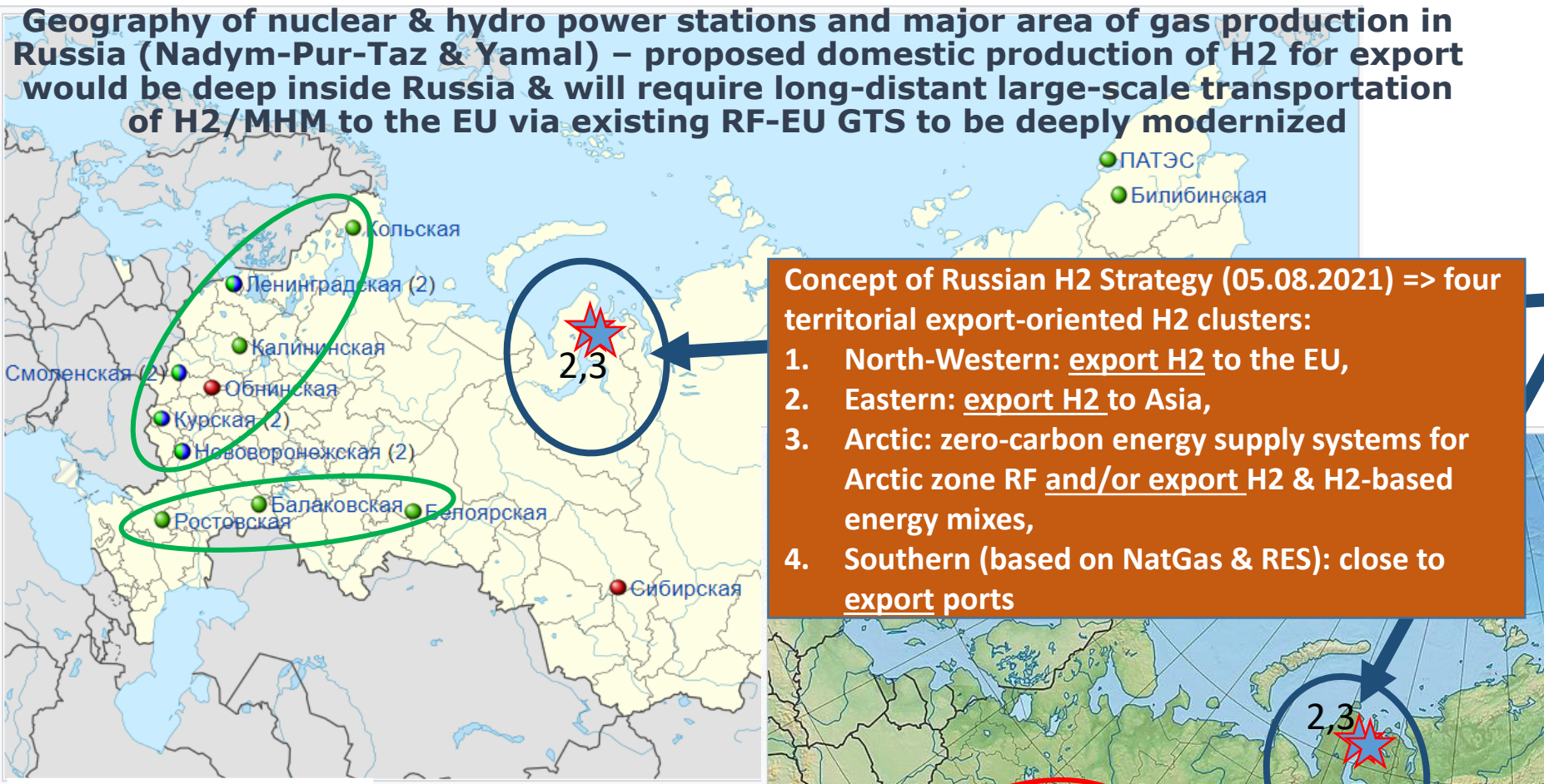
Source: natural gas prices – Gazprom export; H2 costs – European Commission (EU Hydrogen strategy: dotted lines – draft version, May 2020; solid - final document, 08.07.2020)

Russia-EU cooperation prospects in H2 area as seen by different parties: alternatives for H2 supply to the EU



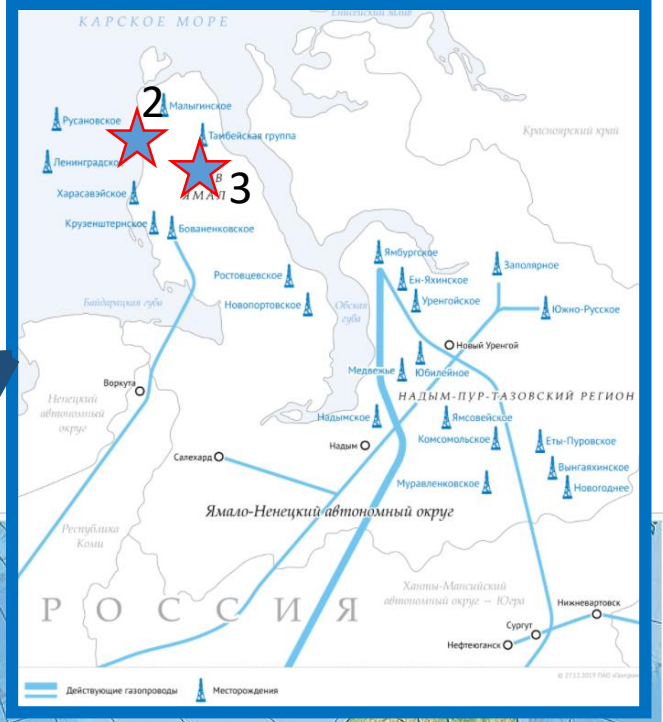
Source: A.Konoplyanik

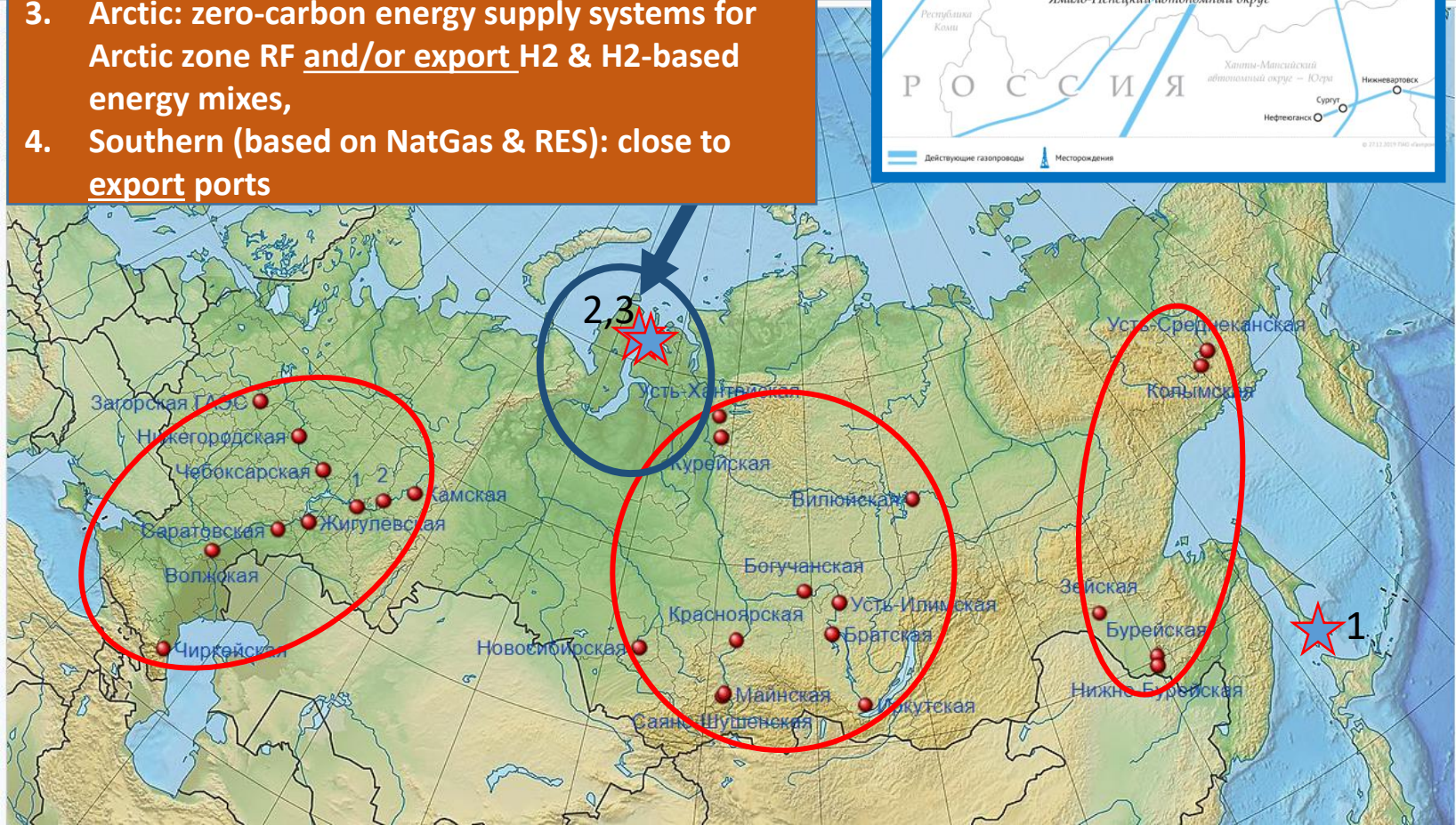
Geography of nuclear & hydro power stations and major area of gas production in Russia (Nadym-Pur-Taz & Yamal) – proposed domestic production of H2 for export would be deep inside Russia & will require long-distant large-scale transportation of H2/MHM to the EU via existing RF-EU GTS to be deeply modernized



Concept of Russian H2 Strategy (05.08.2021) => four territorial export-oriented H2 clusters:

1. **North-Western: export H2 to the EU,**
2. **Eastern: export H2 to Asia,**
3. **Arctic: zero-carbon energy supply systems for Arctic zone RF and/or export H2 & H2-based energy mixes,**
4. **Southern (based on NatGas & RES): close to export ports**





Nuclear

Hydro

Nadym-Pur-Taz & Yamal

Large-scale LNG plants, acting: (1) Sakhalin-2; (2) Yamal LNG; (3) Arctic LNG

Sources of maps:
https://www.gazprom.ru/f/posts/15/770293/map-yamal-ru-2019-12-30.png;
https://ru.wikipedia.org/wiki/Атомная_энергетика_России;
https://ru.wikipedia.org/wiki/Список_гидроэлектростанций_России;

Decarbonisation upstream: some physical & chemical barriers to long-distant high-pressure transportation & storage of H2 (acc. to Litvinenko et al, SPB Mining University) (*)

(1) Effectiveness of gas pipeline transportation is directly contingent upon quantities of the product, and thus on the density of gas. **As concentration of H2 in MHM increases from 10 to 90 %, density of MHM decreases more than four times.**

(2) **Energy obtained from** one volume of **H2 is 3.5 times less than the energy obtained from methane.**

(3) Increase in energy required to compress 1 kg of MHM to raise the pressure by 1 MPa with increasing proportion of H2. While **H2 content in MHM rises from zero to 100%, energy costs (work) are raised by around a factor of 8.5.**

(4) Increasing proportion of H2 in MHM increases explosion risks of the MHM

(5) Export/storage of *liquid* H2: **CH4** liquefies at atmospheric pressure and temperature below - 161.5 °C, LNG volume is 600 times less than its gaseous form. **H2** liquefies at atmospheric pressure and temperature below -252.87 °C, it reduces in volume by 848 times. **(ii)** The closer temperature of a substance to absolute zero, the more **quantum properties** (superfluidity, superconductivity, etc.) begin to appear. **(iii)** Under same conditions and tank capacity it is **possible to store or transport almost 5.9 times more LNG than liquid H2.**

A.Konoplyanik, Gazprom Business Club, 16.09.2021

(6) H2 has extremely high penetrating ability, its molecules spread faster than molecules of all the other gases in the media of another substance and penetrate through almost any metal. **Pressurized H2 is capable to escape even from airtight tanks during long-term storage.**

(7) Research into effect of H2 on metals has been carried out for decades. Back in 1967 in USSR scientific discovery "Depreciative effect of hydrogen on metals“ was made (N 378), however, the reactivity of hydrogen is still not sufficiently studied, whereas its negative effects have already become a substantial technical issue (**stress corrosion**). Due to stress corrosion Gazprom replaced over 5,000 km of large-diameter pipelines.

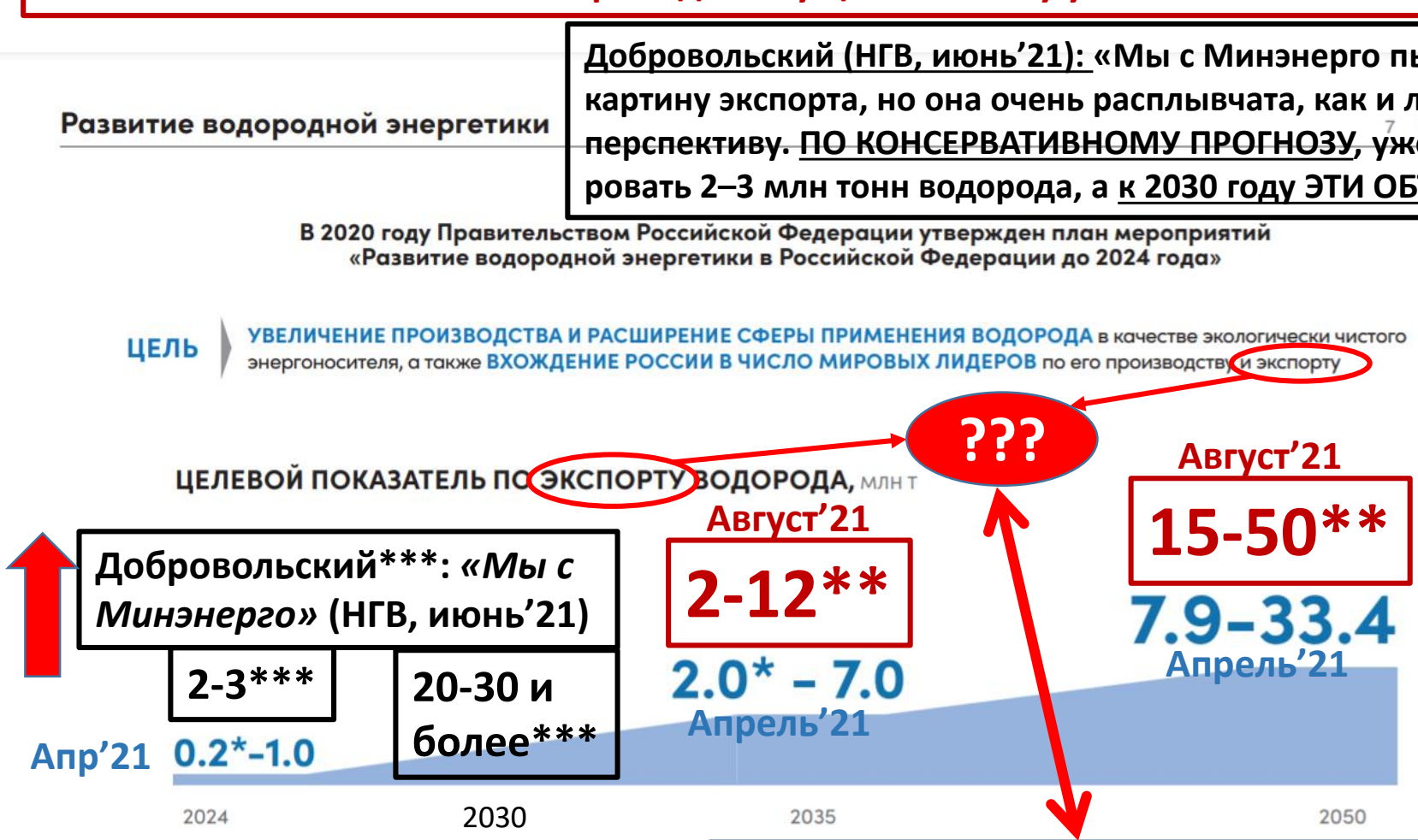
*(*) Within **43** items of RF Gov't Action plan on H2 Saint Petersburg Mining University is mentioned as co-participant in **42** items*

Source: Litvinenko V.S., Tsvetkov P.S., Dvoynikov M.V., Buslaev G.V., Eichlseder W. Barriers to implementation of hydrogen initiatives in the context of global energy sustainable development. Journal of Mining Institute. 2020. Vol. 244, p. 428-438. DOI: 10.31897/PMI.2020.4.5

Минэнерго/Правительство РФ: все более амбициозная ставка на экспорт водорода, но вопрос о его доставке на экспортные рынки технически не решен, а озвучиваемые «экспертами» решения – контрпродуктивны, непрофессиональны и разорительны…

Концепция водородной стратегии РФ, п.18 (05.08.2021): технологии транспортировки и хранения H2, применяемые в настоящее время, недостаточно отработаны в промышленности, имеют неудовлетворительные технико-экономические показатели и приводят к существенному увеличению стоимости H2

Добровольский (НГВ, июнь'21): «Мы с Минэнерго пытались спрогнозировать будущую картину экспорта, но она очень расплывчата, как и любые прогнозы на отдаленную перспективу. ПО КОНСЕРВАТИВНОМУ ПРОГНОЗУ, уже в 2025 году Россия сможет экспортировать 2–3 млн тонн водорода, а к 2030 году ЭТИ ОБЪЕМЫ МОГУТ ВЫРАСТИ В ДЕСЯТКИ РАЗ».



Источник:
Базисный слайд: Итоги работы Минэнерго России и основные результаты функционирования ТЭК в 2020 году. Задачи на 2021 год и среднесрочную перспективу. Материалы заседания Коллегии Минэнерго России, 12 апреля 2021 г., слайд 7 (https://minenergo.gov.ru/system/download-pdf/20322/154219)
(**) Концепция развития водородной энергетики в РФ. Утверждена распоряжением Правительства РФ от 5 августа 2021 г. № 2162-р (http://static.government.ru/media/files/5JFns1CDAKqYKzZ0mnRADAw2NqcVsexl.pdf)
(***) Ю.Добровольский. Водороду нужна господдержка. // «Нефтегазовая Вертикаль», июнь 2021, №11-12, с.80-84 (84) (http://www.ngv.ru/upload/iblock/ad7/ad759fe2657454a1adbe4d7435d1fba3.pdf)

Это означает производство H2 внутри страны и его дальнюю транспортировку на экспортные рынки (в ЕС, Азию, ???). Каким образом? ГТС - H2/МВС? Жидкий H2?

Approximate potential areas of preferential use of key H2 production technologies in Europe under state regulation based on "technological neutrality" principles – potential new competitive niche for Russian gas & technologies for H2 production w/o direct CO2 emissions

Source: dashed lines - A.Konoplyanik, based on conversations with Ralf Dickel; dotted lines - Ukraine & North Africa are added based on "The 2x40GW Green Hydrogen Initiative Paper" Hydrogen Europe study for illustration purposes with the observation of this author's skepticism in regard to long-distance transportation of H2 produced in these geographical areas

Map source: ENTSOG

А.Конопляник, Zoom-заседание Экономического клуба ФБК "Россия без нефти: рецепты выживания«, 09.06.2020

P2G wind

P2G solar

P2G hydro

P2G nuclear

«Clean» H2 (EU: **«green»**, renewable H2)

Pre-determined EU priority

MSR/ATR plus CC(U)S

Decarbonised (low-carbon) H2 (EU: **«blue»**)

Accepted temporary solution for the EU

Methane pyrolysis, plasma-chemical method et al w/o access O2 & CO2 emissions

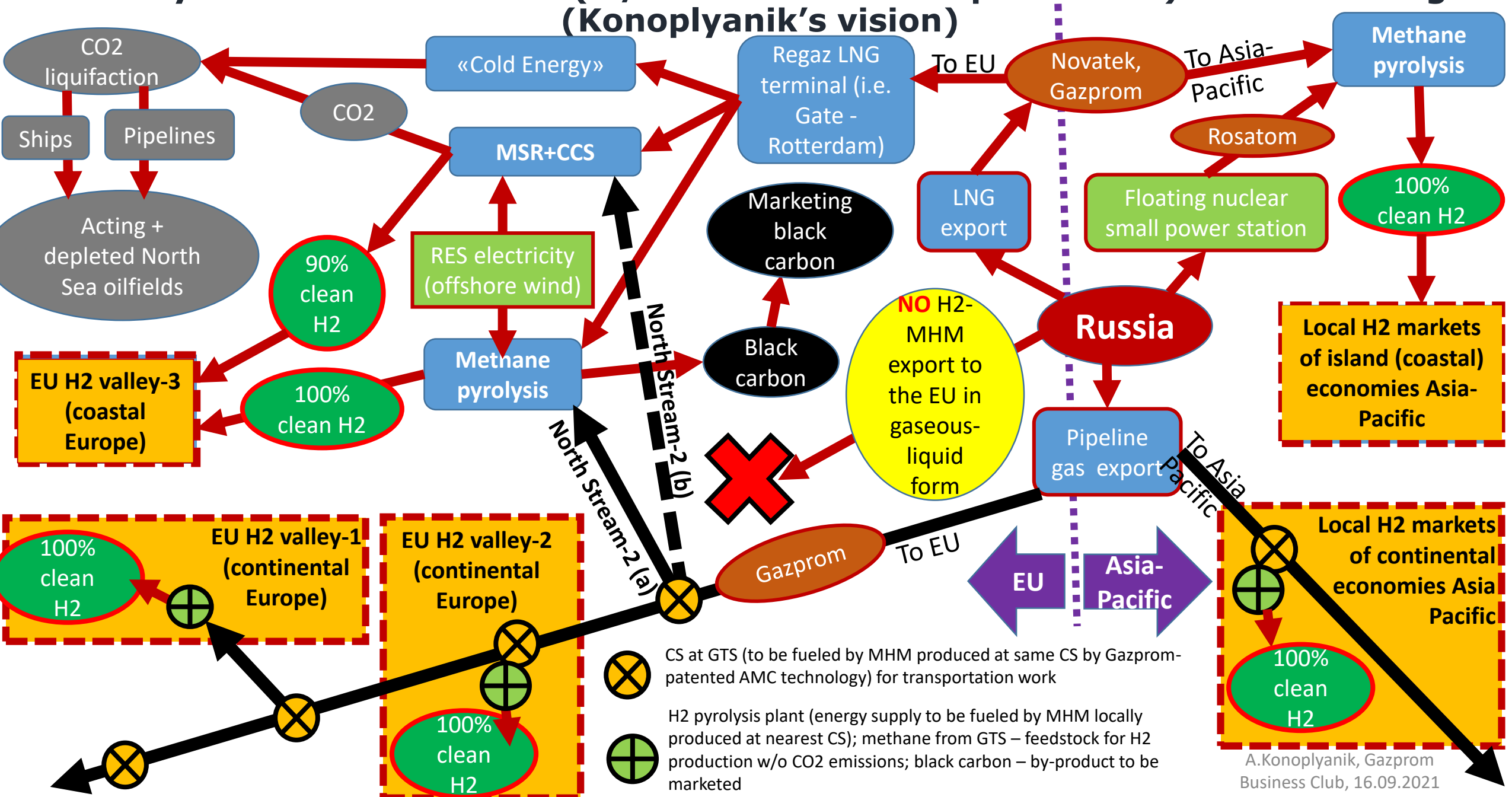
«Clean» H2 (EU: **«turquois»**)

Mutually acceptable (beneficial) long-term solution RF & EU

Clean H2 production (w/o CO2 emissions) from natural gas downstream EU based on existing Russia-EU GTS & MHM (as energy source) produced at CS on-site

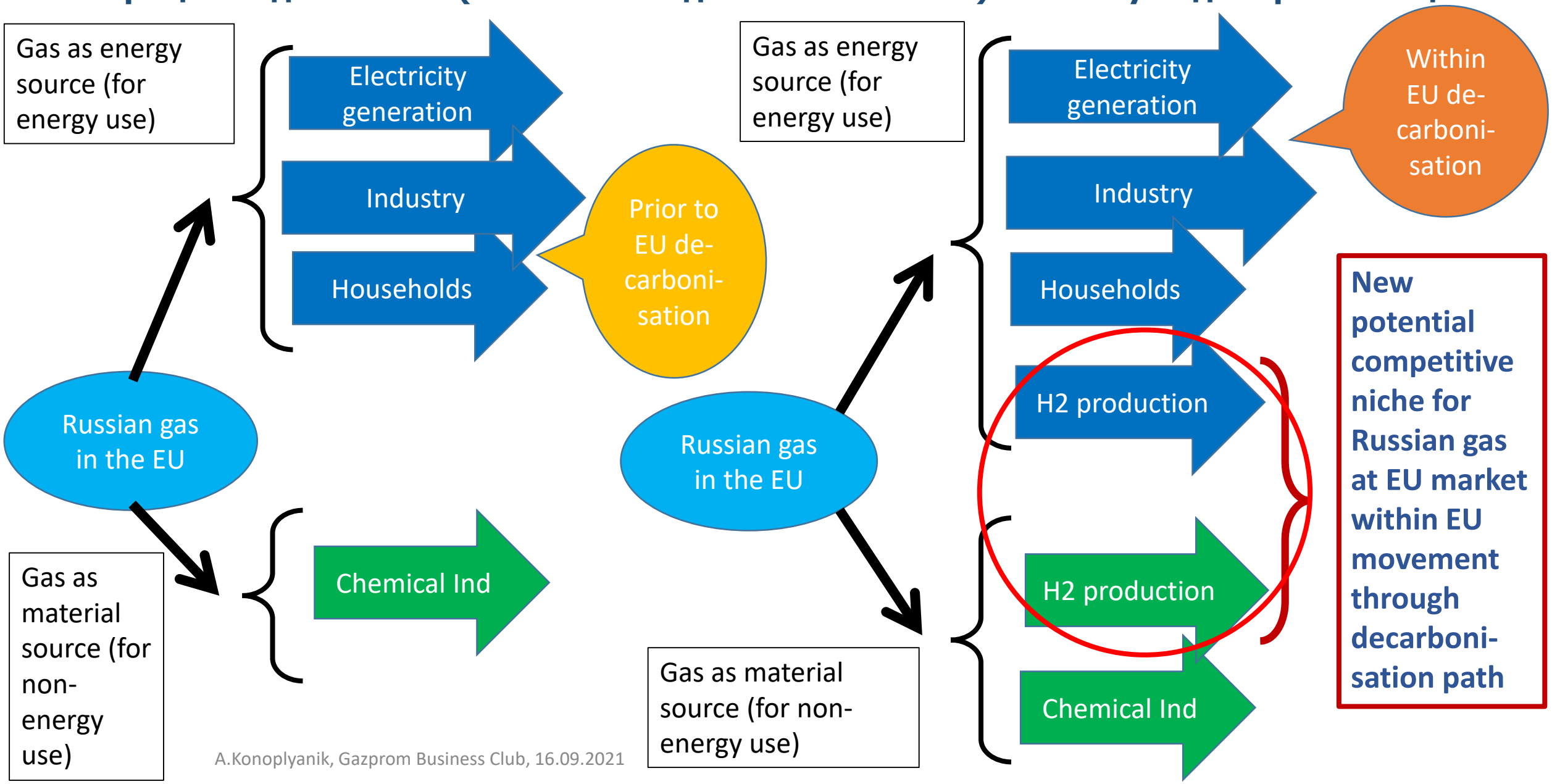
- Clean H2 production close to EU demand centers (H2 valleys) located close to existing compressor stations (CS) at cross-border RF-EU GTS. To use gas from the grid:
- As **energy source** for:
  - (1) transportations work:
    - to produce MHM on-site at CS on transportation routes of Russian gas to the EU;
    - to use this MHM at these CS as a fuel gas instead of methane for further gas transportation.
    - Such substitution of CH4 by MHM as fuel gas at CS diminishes CO2 emissions by 30% (acc.to Gazprom);
  - (2) clean H2 production:
    - at the H2 production plants which are to be built close to these CS in “H2 valleys”;
    - scale of production adequate to H2 demand of particular “H2 valley”;
    - energy supply of CCGT of adequate capacity - acc.to above-mentioned scheme in (1).
    - Though substitution of CH4 by MHM as fuel gas is not for transportation work, but for energy supply (electricity &/or heat) to H2 production plant;
- As a **feedstock** for:
  - (3) clean H2 production:
    - new plants for clean H2 production from CH4 (pyrolysis et al);
    - plants to be located close to CS and aimed to cover H2 demand of local “H2 valley” (this will exclude demand for long-distance transportation of H2 or MHM).

Alternative concept for export-oriented segment of Russian hydrogen energy economy – based on clean H2 (w/o CO2 emission in production) from natural gas (Konoplyanik's vision)



A.Konoplyanik, Gazprom
Business Club, 16.09.2021

Конкурентные ниши для российского газа на рынке газа ЕС до начала (существующие) и в процессе движения (возможные дополнительные) ЕС по пути декарбонизации



Thank you for your attention!

www.konoplyanik.ru
andrey@konoplyanik.ru
a.konoplyanik@gazpromexport.com

Disclaimer: Views expressed in this presentation do not necessarily reflect (may/should reflect) and/or coincide (may/should be consistent) with official position of Gazprom Group (incl. Gazprom JSC and/or Gazprom export LLC), its stockholders and/or its/their affiliated persons, or any Russian official authority, and **are within full personal responsibility of the author of this presentation.**

Note: Research is undertaken with financial support of Russian Foundation for Fundamental Research (RFFR) within the project "Influence of new technologies on global competition at the raw materials markets", project № 19-010-00782