Prof. Dr. Andrey Konoplyanik

Hydrogen strategies EU, Germany, Russia: how to correlate different interests & the role of Russia–EU Energy Dialogue

The topic of this article is how to create a bridge between Russia and European Union in developing energy transition, in particular in developing cooperative efforts, how best effectively my country Russia – the sovereign state with its national sovereign interests – can help European Union in developing its national strategy of decarbonisation with its sovereign aims and with its national interests in this area. What will be the common denominator area between the two, and whether it will be possible and manageable, which is nor less important, to expand this area of common denominator to the mutual benefit of the two.

EU Green Deal & EU vision of cooperation in H2

The European Green Deal adopted in 2019 sets the goal to achieve carbon neutrality in the EU by 2050, relying on the development of RES and decarbonized gases, and hydrogen (H_2) as a priority. The EU Hydrogen Strategy of 08.07.2020[1] is focused on "renewable" H_2 produced by electrolysis using (mostly surplus) electricity from renewable energy sources. However, it is recognized in the EU that the predicted amounts of "renewable" H_2 to be produced by 2050 will not be sufficient for achieving the goal of zero emissions[2]. Therefore, both imports of H_2 and its production from natural gas are deemed acceptable. The latter is allowable solely by methane steam reforming (MSR) with mandatory CO_2 capture and sequestration technologies (CCS). Nonetheless, it is firmly stated that H_2 from natural gas is only a temporary (unwanted but forced) path to "renewable" H_2. Thus, the ultimate goal of the EU hydrogen philosophy in terms of hydrogen sources is using only/mostly "renewable" H_2 that can be produced within the EU or imported.

Meanwhile, in order to make domestic production of "renewable" H_2 in the EU as efficient as possible, European producers of equipment (high-capacity electrolysers) need to secure a capacious market, both in the EU and beyond, to benefit from the economy of scale and learning curve, i.e. to reduce unit costs with the growth of equipment capacity and accumulation of experience in its operation. This is the aim of the concept of foreign economic cooperation with neighboring countries in the field of hydrogen energy, which is promoted by the EU, its member states (for example, Germany) and their business associations (for example, the German-Russian Chamber of Foreign Trade and the German Committee on Eastern European Economic Relations)[3].

---

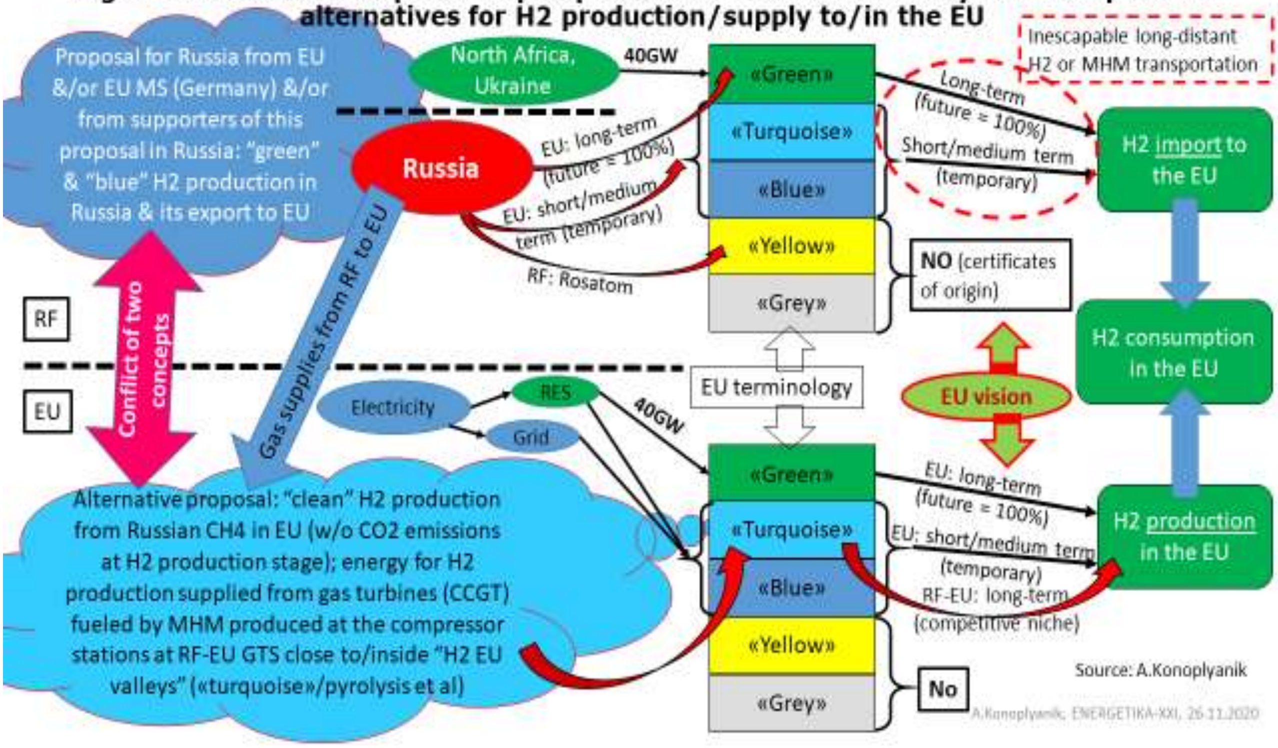
[1] COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS A hydrogen strategy for a climate-neutral Europe. Brussels, 8.7.2020 COM(2020) 301 final (https://ec.europa.eu/energy/sites/ener/files/hydrogen_strategy.pdf)

[2] R.Dickel. Blue hydrogen as an enabler of green hydrogen: the case of Germany. // Oxford Institute for Energy Studies (OIES), OIES Paper: NG 159, June 2020 (https://www.oxfordenergy.org/wpcms/wp-content/uploads/2020/06/Blue-hydrogen-as-an-enabler-of-green-hydrogen-the-case-of-Germany-NG-159.pdf#page=17&zoom=100,92,440)

[3] ВТП выступает за партнерство РФ и ФРГ в сфере водородной энергетики. Пресс-релиз. Москва, 7 июля 2020 (https://russland.ahk.de/ru/mediacentr/novosti/detail/vtp-vystupaet-za-partnerstvo-rf-i-frg-v-sfere-vodorodnoi-

The EU, primarily Germany (using the funds allocated by the German government to promote the interests of German business abroad, which are two billion euros out of total nine billion euros earmarked to facilitate the creation of large-scale production, starting with large-scale pilot plants based on German technologies and equipment) proposes to build hydrogen cooperation with Russia based on developing H_2 production in Russia, either by electrolysis with electricity generated by nuclear and/or hydro power stations, or by MSR+CCS from natural gas produced in Russia's main gas production regions (Nadym-Pur-Taz, Yamal). In the latter case, it is proposed to inject CO_2, thus generated, into the productive formations of oil fields in Western Siberia to enhance oil recovery, and to export H_2 or methane-hydrogen mixture (MHM) to the EU. But one need to bear in mind the placement at the geographical map of Russia locations of nuclear and hydro power stations (where it is proposed to produce green/renewable H_2), as well as major gas fields (where blue H_2 is proposed to produce by MSR) and oil fields (in which CO_2 emitted by MSR facilities located at the gas fields is to be injected to increase oil recovery) – all of them are located deep inside Russia, in thousands of miles far away from key potential H2 consumption centers (EU H2 valleys) deep inside the EU, mostly in North-West Europe.

Figure 1. Russia-EU cooperation prospects in H2 area as it seen by different parties: alternatives for H2 production/supply to/in the EU



This means that such proposal will necessitate long-distance transportation of H_2 or MHM and, therefore, profound modernization or even complete replacement of the existing cross-border gas transportation system (GTS) between Russia and EU to shift from transporting methane to transporting H_2/MHM; most of the work will have to be done outside the EU, that is, inside Russia (see **Figure 1**).

---

ehnergetiki); Позиция ВТП по партнерству РФ и ФРГ в сфере водородной энергетики. 07.07.2020 (https://russland.ahk.de/ru/mediacentr/novosti/detail/pozicija-vtp-za-partnerstvo-rf-i-frg-v-sfere-vodorodnoi-ehnergetiki)

Some hotheads suggest to begin with adapting Nord Stream-2 gas pipeline (now at the end of its construction stage) for H_2 transportation (simple-heartedly suggesting that this will ease US exterritorial sanctions against this gas pipeline) and then, probably, to build a Nord Stream-3 or even Nord Stream-4, each comprising two lines dedicated for H_2 transportation[4].

Russian vision of developing hydrogen economy

The "Energy Strategy of the Russian Federation Until 2035" (09.06.2020)[5] is the first document of its kind to include a "Hydrogen Energy Economy" section. The stated aim is that Russia to become one of world leaders in H2 production and export. Key measures to achieve these aims are: state support for development of infrastructure for transport and consumption of H2 & methane-hydrogen-mixes (MHM); state support for H2 production; stepping up H2 from CH4 production, incl. with RES, nuclear; development of domestic low-carbon technologies of H2 production by gas conversion & pyrolysis, electrolysis, etc., incl. possible localization of foreign technologies; stimulate domestic demand for fuel cells; in transport, H2 & MHM use to accumulate & convert energy; develop regulatory base for hydrogen safety in energy; intensify international cooperation in H2 energy development & entry to foreign markets.

Criteria for H2 energy development is indicated as "export of H2". And the key objectives are formulated as bringing H_2 exports to 0.2 mln.t and 2 mln.t by 2024 and 2035, respectively.

For comparison: today global H2 market is around 75-80 million tonnes per annum (MTPA). In Europe it is currently about 8.3 MTPA with the aim to reach in 2030 about 20 MTPA (in the programme "2 X 40 GW" incorporated now in the EU H2 Strategy).

Export-oriented provisions in Russian Energy Strategy have been clearly interpreted in Russia and abroad as a focus on producing H_2 inside Russia and subsequent export of H_2 or MHM, which, unfortunately, reflects the imposed on Russia (this is just what German colleagues are proposing) and, in my opinion, counter-productive concept for developing the foreign economic segment of Russia's hydrogen strategy. Such reading is clearly demonstrated, for instance, in the international comparison of H2 strategies[6] (see **Figure 2**) based on perceptions (straightforward interpretations) of H2 section in Russian Energy Strategy up to 2035; internal debate in the course of its preparation; & dominant EU (i.e. German) vision of Russia's H2 strategy developments.

---

[4] В.Б.Белов. Водородная энергетика – новая ниша российскоз-германской кооперации. Аналитическая записка №37, 2020 (№220) (http://www.instituteofeurope.ru/images/uploads/analitika/2020/an220.pdf); Steve Cowan. In Russia, they started talking about "Nord stream-3". // "Free News", 04.10.2020 (https://freenews.live/in-russia-they-started-talking-about-nord-stream-3/); В.Белов. Новые водородные стратегии ФРГ и ЕС: перспективы кооперации с Россией. // «Современная Европа», 2020, № 5, с. 65–76 (DOI: http://dx.doi.org/10.15211/soveurope520206576)

[5] Энергетическая стратегия Российской Федерации на период до 2035 года. Утверждена распоряжением Правительства Российской Федерации от 9 июня 2020 г. № 1523-р. (http://static.government.ru/media/files/w4sigFOiDjGVDYT4IgsApssm6mZRb7wx.pdf)

[6] INTERNATIONAL HYDROGEN STRATEGIES. A study commissioned by and in cooperation with the World Energy Council Germany, FINAL REPORT. Dr. Uwe Albrecht, Dr. Ulrich Bünger, Dr. Jan Michalski, Tetyana Raksha, Reinhold Wurster, Jan Zerhusen, Ludwig Bölkow-Systemtechnik GmbH, September 2020, (https://www.weltenergierat.de/wp-content/uploads/2020/10/WEC_H2_Strategies_finalreport.pdf)

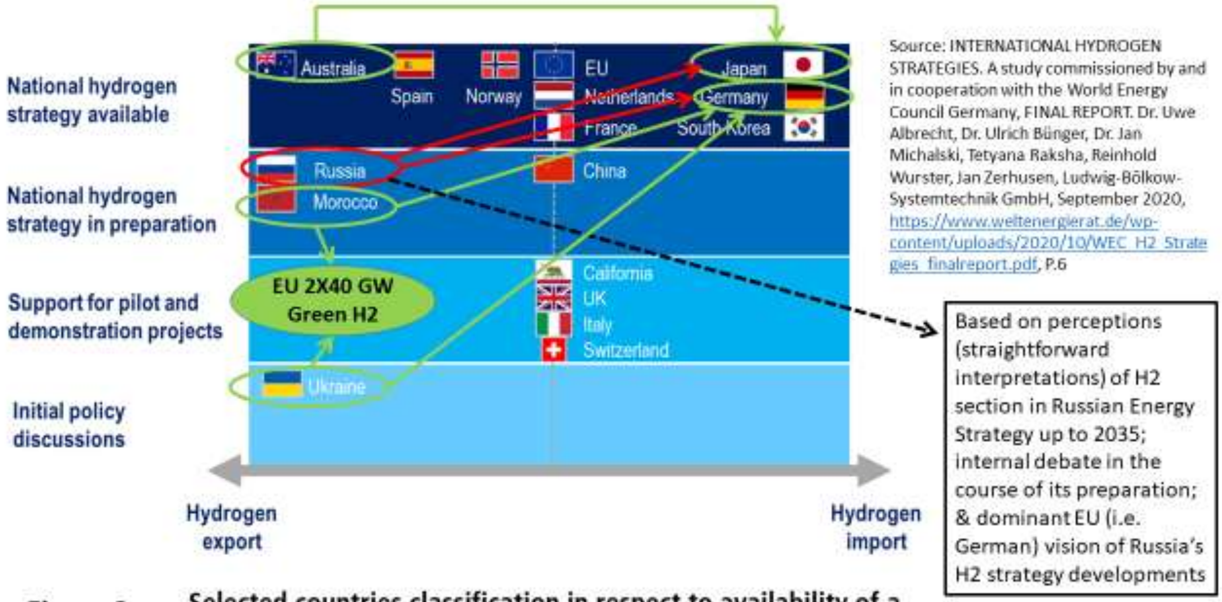


Figure 2. Selected countries classification in respect to availability of a dedicated strategy and hydrogen imports/exports

A.Konoplyanik, ENERGETIKA-XXI, 26.11.2020

Though this same source identified Russia as the only state in the analyzed list, which until 2050 plan to utilize all available options for H2 production and not limit them only to green H2 route (see **Figure 3**).

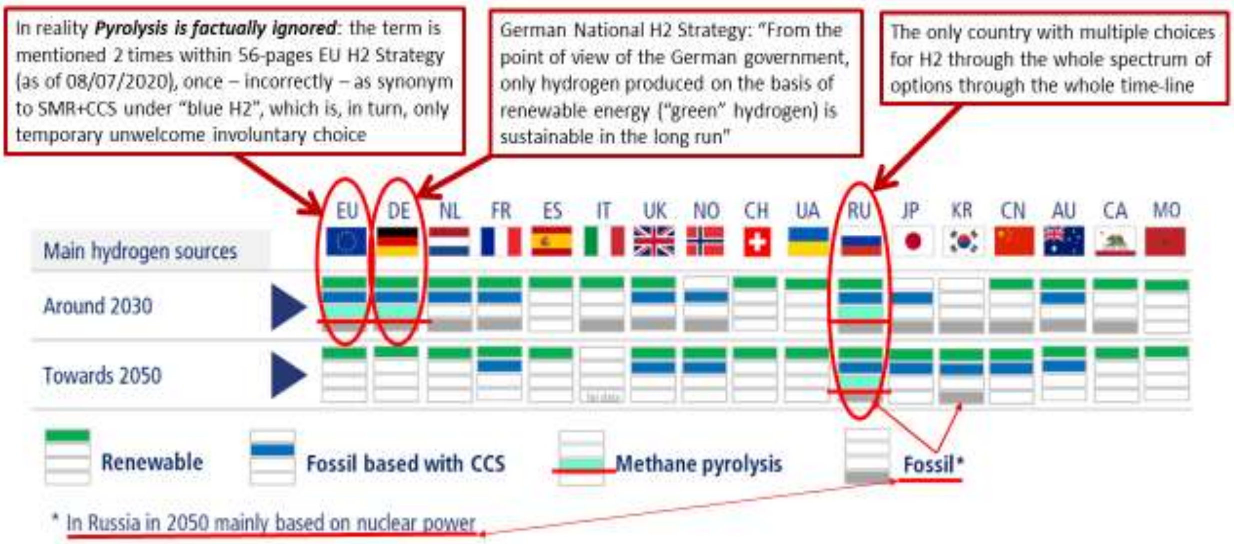


Figure 3. Considered medium- and long-term hydrogen production options by country

Source: INTERNATIONAL HYDROGEN STRATEGIES. A study commissioned by and in cooperation with the World Energy Council Germany, FINAL REPORT. Dr. Uwe Albrecht, Dr. Ulrich Bünger, Dr. Jan Michalski, Tetyana Raksha, Reinhold Wurster, Jan Zerhusen, Ludwig-Bölkow-Systemtechnik GmbH, September 2020, https://www.weltenergierat.de/wp-content/uploads/2020/10/WEC_H2_Strategies_finalreport.pdf, P.33 A.Konoplyanik, ENERGETIKA-XXI, 26.11.2020

Nevertheless, the same study has made wrong perception on long-distance transportation of H2 considered it to be as available (technologically proven) as long-distance transportation of CH4 (see **Figure 4**) – which is not the case!!!

Figure 4. **Principle technology availability of main export/import technologies**

A.Konoplyanik, ENERGETIKA-XXI, 26.11.2020

Alternative vision for Russia

The “RF Government Action Plan for Developing Hydrogen Energy Economy Until 2024” (12.10.2020)[7] in fact corrects the distorted perception of the Energy Strategy’s goal-setting, for it no longer talks about exports, but about “creating a highly productive export-oriented segment of hydrogen energy,” and paragraphs 39-43 of the Plan require submitting proposals for international cooperation (see **Figure 5**).

This means that the Government Action Plan has laid a foundation to form an alternative model of cooperation between Russia and the EU in this area. The above concept of RF-EU hydrogen cooperation proposed by our EU partners (and supported by a number of Russian “experts”) is counterproductive, from my view. After all, it has been demonstrated and convincingly proven (for example, in the works by V.S. Litvinenko and his colleagues from St. Petersburg Mining University[8]) that, due to objective physical and chemical reasons and unresolved technical problems (flow density, energy obtained from equal volumes, energy consumption for compression, storage volumes in comparable containers, problems of hydrogen embrittlement and stress-corrosion), long-distance transportation and storage of H_2/MHM in gaseous and/or liquefied form is drastically inferior, in terms of reliability,

---

[7] План мероприятий «Развитие водородной энергетики в Российской Федерации до 2024 г.». Утвержден распоряжением Правительства Российской Федерации от 12 октября 2020 г., № 2634-р (http://static.government.ru/media/files/7b9bstNfV640nCkkAzCRJ9N8k7uhW8mY.pdf)

[8] Литвиненко В.С., Цветков П.С., Двойников М.В., Буслаев Г.В. Барьеры реализации водородных инициатив в контексте устойчивого развития глобальной энергетики // Записки Горного института, 2020, т. 244, с. 428-438. DOI: https://doi.org/10.31897/pmi.2020.4.421 (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. DOl: 10.31897/PMI.2020.4.5).

safety and economy, to long-distance transportation and storage of natural gas in gaseous state or in the form of LNG (see **Figure 6**).

Figure 5. Hydrogen action plan in Russia up to 2024: some key elements related to clean H2 from CH4 and to international cooperation (acc. to RF Governmental Ordinance as of 12.10.2020)

No	Task	Time
1.1-3	To develop Hydrogen strategy, Project office for realization of H2 strategy, Interagency Task Force	2021-Q1
2.7	To develop state support measures for priority pilot projects of H2 for energy use, incl. demonstration	2021-Q1
2.8	To develop state support measures for **export of H2** for energy use **(different interpretations/perceptions possible)**	2021-Q2
3.11	System of criteria to select priority projects	2021-Q1
3.12	To develop & annually adjust the list of priority projects	2021-Q1
3.14	Suggestions on engineering centers (to monitor & adjust annually)	2021-Q1
4.15	To provide for creation, manufacturing & implementation of **pilot projects for H2 production without CO2 emissions**	2024
4.16	To provide for creation of test-fields for **low-carbon H2 production** at O&G refining facilities & on **gas production sites**	2023
4.17	To provide for creation, manufacturing & testing of **gas turbines on methane-H2 mix (MHM)**	2024
4.19	To provide for realization of pilot project of **H2 production based on existing nuclear power stations**	2023
5.20	To develop & annually adjust the Register of existing & prospective H2 technologies	2021-Q1
5.21	To provide for development of domestic energy-efficient technologies of production, **transportation & storage of H2**; approbation of **H2 & MHM as a fuel** (with different content of H2 in MHM) **for gas turbines & boilers**	2021-2024
5.22	Research of technologies & their full production cycles GHG-tracks for different production, transportation & utilization	2021-2024
5.24	Research on **marketing of carbon black**	2021-2024
5.25	Proposals for System of certification fro decarbonized H2	2021-Q2
6.27,32	National system of standardization H2+MHM; external cooperation in standardization MHM	2021-Q1,4
8.39-43	International cooperation (*to prepare proposals*) **(=> critical stage – NOW - for domestic & international debate!!!)**	2020-2024

A.Konoplyanik, ENERGETIKA-XXI, 26.11.2020

At the same time, a number of recent studies published in the EU/Germany (e.g. the April'2020 publication of the Hydrogen Europe association[9]; the July'2020 publication of eleven EU GTS operators[10]; the September'2020 report of four German companies led by Siemens[11]; etc.) are trying to prove the opposite.

But as it appears to me after their attentive reading, these works contain obvious overstatements and internal contradictions (see **Figure 6**, right part). They tries to convince both sides of the acceptability of the proposed model of RF-EU cooperation on hydrogen: to produce H_2 domestically in Russia and to export it to the EU either through dedicated hydrogen infrastructure or through gas infrastructure modernized to long-distance transport of H_2 or MHM.

---

[9] Prof. Dr. Ad van Vijk, Jorgo Chatzimarkakis. Green Hydrogen for a European Green Deal. A 2X40Gw initiative.// Hydrogen Europe, 03/2020, 41 pp. (обнародовано 15.04.2020) (https://hydrogeneurope.eu/sites/default/files/Hydrogen%20Europe_2x40%20GW%20Green%20H2%20Initative%20Paper.pdf)

[10] European Hydrogen Backbone. How a Dedicated Hydrogen Infrastructure Can Be Created. // Enagás, Energinet, Fluxys Belgium, Gasunie, GRTgaz, NET4GAS, OGE, ONTRAS, Snam, Swedegas, Teréga, July 2020, 29 pp. (https://gasforclimate2050.eu/sdm_downloads/european-hydrogen-backbone/)

[11] Peter Adam, Frank Heunemann, Christoph von dem Bussche, Stefan Engelshove, Thomas Thiemann. Hydrogen infrastructure – the pillar of energy transition The practical conversion of long-distance gas networks to hydrogen operation. // Siemens Energy, Gascade Gastransport GmbH, Nowega GmbH, Whitepaper, 2020, 32 pp. (https://assets.siemens-energy.com/siemens/assets/api/uuid:3d4339dc-434e-4692-81a0-a55adbcaa92e/200915-whitepaper-h2-infrastructure-en.pdf)

Figure 6. Decarbonisation upstream: different view from East & West on long-distant high-pressure transportation & storage of H2

Litvinenko et al, SPB Mining Univ.

1) concentration of H2 in MHM increases from 10 to 90 % => **density of MHM decreases more than 4 times.**
2) **Energy** obtained **from H2 is 3.5 times less** than the energy obtained from methane.
3) H2 content in MHM rises from zero to 100% => **energy use** (required to compress 1 kg of MHM to raise the pressure by 1 MPa) **increased by around a factor of 8.5.**
4) it is possible to store or transport **almost 5.9 times more LNG than liquid H2.**
5) Pressurized H2 is **capable to escape** even from airtight tanks during long-term storage.
6) **Stress corrosion**: due to it Gazprom replaced over 5,000 km of large-diameter pipelines.

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.

Siemens/Gascade/Nowega

1) Pure hydrogen, as an energy source in pipelines, has an **almost comparable** transport energy **density** as natural gas. [...] Contrary to popular belief, the transport energy **density** of hydrogen is **only slightly lower** than that of natural gas. Therefore, the switch from natural gas to hydrogen has little impact on the capacity of a pipeline to transport energy. [...] hydrogen has a **density nine times lower** and three times the flow rate of natural gas, almost three times the volume of hydrogen can be transported in the pipeline at the same pressure, and during the same time. The energy density is only lightly reduced [...] Transport via pipelines is particularly economical. Due to the high calorific value and the compressibility of the hydrogen, an **extraordinarily high energy density** can be achieved.
2) The pipeline networks are available, socially accepted, and can be gradually converted to hydrogen operation with an investment of an **estimated 10-15% of the cost** of new construction [...] As measuring devices, compressors and fittings can be exchanged relatively easily, *(AK: BUT??? =>)* replacing or building new pipelines would be **very expensive.** [...] To enable optimal utilization with high transport energy density in hydrogen operation, more and higher-power compressors are required than in natural gas operation. [...] approximately **three times** the drive power and therefore a correspondingly **higher number of turbines and compressors** are required than in natural gas operation.
3) ...it is **possible to convert** the existing steel pipelines from natural gas to hydrogen operation to the extent required for the ramp-up of a hydrogen industry. A significant **reduction in the service life** of high-pressure lines due to the influence of hydrogen **does not seem likely**
4) ...hydrogen transport capacities **can initially be built up in parallel** and cumulatively with existing natural gas systems. [...] **A parallel hydrogen and natural gas infrastructure at the long-distance gas level** also offers the possibility of adapting the composition of the gas

Source: Hydrogen infrastructure – the pillar of energy transition. The practical conversion of long-distance gas networks to hydrogen operation. // Whitepaper. Siemens Energy, Gascade Gas Transport GmbH, Nowega GmbH, 2020, 32 p.

A.Konoplyanik, ENERGETIKA-XXI, 26.11.2020

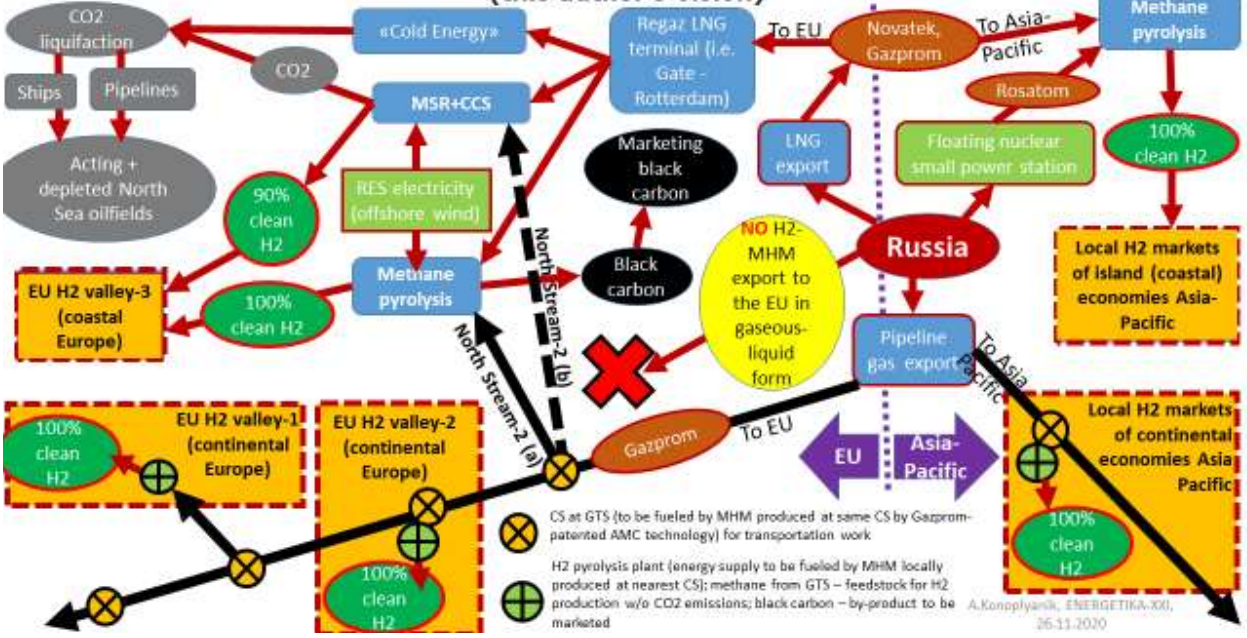
Incidentally, the authors of these studies are the main potential beneficiaries of the proposed hydrogen infrastructure. They are either direct hydrogen promoters by their statute (Hydrogen Europe), or equipment manufacturers (Siemens et al) looking for expansion of their market share, or GTS operators for whom implementation of the idea will increase the amount of assets under their management. But all risks and responsibilities, including those resulting from a complete change in the equipment, logistics and contractual structure of supplies when switching from natural gas to H_2/MHM, will be borne by shippers, including those from outside the EU. In case of Russia, these risks and responsibilities will be borne by Gazprom – the economic agent of the Russian government (the sovereign owner of non-renewable natural resources – gas), entrusted to monetize these resources when transporting produced gas to foreign markets through pipelines.

Therefore, in my opinion, the concept of hydrogen cooperation proposed by our European partners (the export section of the emerging hydrogen strategy of Russia) is unacceptable, because it does not serve Russia's national interests, specifically, the task of effective monetization of Russian natural gas resources and effective use of the existing gas infrastructure, first of all, the cross-border GTS between Russia and the EU. Though this concept completely reflects the national interests of the EU (Germany) and the businesses of these countries. But the mutually beneficial cooperation roadmap should be based on the balance of interests of both parties involved, and not on unilateral interests of one side only.

Mutually beneficial roadmap for hydrogen cooperation

Based on existing developments, including those of Gazprom, I propose an alternative concept of hydrogen cooperation between Russia and the EU (see **Figure 7**). It is based on exporting Russian natural gas to the EU via the existing GTS as well as in the form of LNG, and H_2 production inside the EU in areas of most rapidly growing demand for H_2 ("hydrogen valleys") by methane pyrolysis (or similar technologies that allow producing "clean" H_2, i.e. without any CO_2 emissions at the production stage, like with electrolysis) or by MSR+CCS in the coastal areas of North West Europe with CO_2 removal.

Figure 7. Alternative concept for export-oriented segment of Russian hydrogen energy economy – based on clean H2 (w/o CO2 emission in production) from natural gas (this author's vision)



In case of LNG supplies to regasification terminals in the coastal areas of Northwestern Europe as well as pipeline gas supplies via Nord Stream 1 and 2, RES electricity from offshore wind farms in the North Sea can be used to produce H_2 by pyrolysis or MSR. Carbon dioxide emitted in the MSR process can be liquefied using the "cold energy" generated by LNG regasification plants and transported by tankers or via the existing pipelines (operated in reverse mode) to both operational and abandoned oil fields in the North Sea for injection into the productive formations either for increasing oil recovery in the first case, or for CO_2 sequestration in the second case (Gasunie, Equinor, Shell and some other companies are working on this option). In case of H_2 production by pyrolysis or similar methods, i.e. without oxygen access and hence without CO_2 emissions (first prototypes of such installations are projected to appear in Russia by 2024, according to Government H2 Action Plan, but might appear earlier in case of Russia-EU cooperation), the opportunities for H_2 production will expand dramatically, especially in continental Europe.

In this case, natural gas supplied via the RF-EU GTS will be used within continental Europe (see **Figure 8,** area circled by black dotted line):

- as an energy resource:
  - to perform transportation services: for producing MHM at GTS compressor stations (CS) along the routes of Russian gas transportation to the EU and using MHM at the same CSs as fuel gas (instead of methane) for further gas pumping through the network. Such substitution (based on adiabatic methane conversion (AMC) technology patented by Gazprom; pilot plants should be presented up to 2024, according to Russian Government H2 Action Plan, but in case of Russia-EU cooperation can be, most

probably, commercialized earlier) will result in a one-third reduction of CO_2 emissions at the compressor stations[12];

- to produce “clean” H_2 from natural gas at pyrolysis plants to be built in the immediate neighborhood of these CSs in areas of particularly rapid growth of demand for H_2 (“hydrogen valleys” of the EU) in amounts corresponding to expected demand for H_2 in the neighborhood of these “valleys”. Fuel supply to gas (steam-gas) turbines of appropriate capacity can be arranged according to the same pattern as specified in the previous paragraph, although methane will be substituted with MHM not for the purpose of performing transportation work, but for generating electricity and/or thermal energy needed for producing “clean” H_2;

- as a feedstock:
  - for new pyrolysis plants producing “clean” H_2 from methane, which will be located near these CSs and aimed at satisfying local (rather than all-European) demand (within the nearest “hydrogen valleys”) in order to minimize the need for long-distance transportation of H_2 as well as for the creation of new specialized transportation systems.

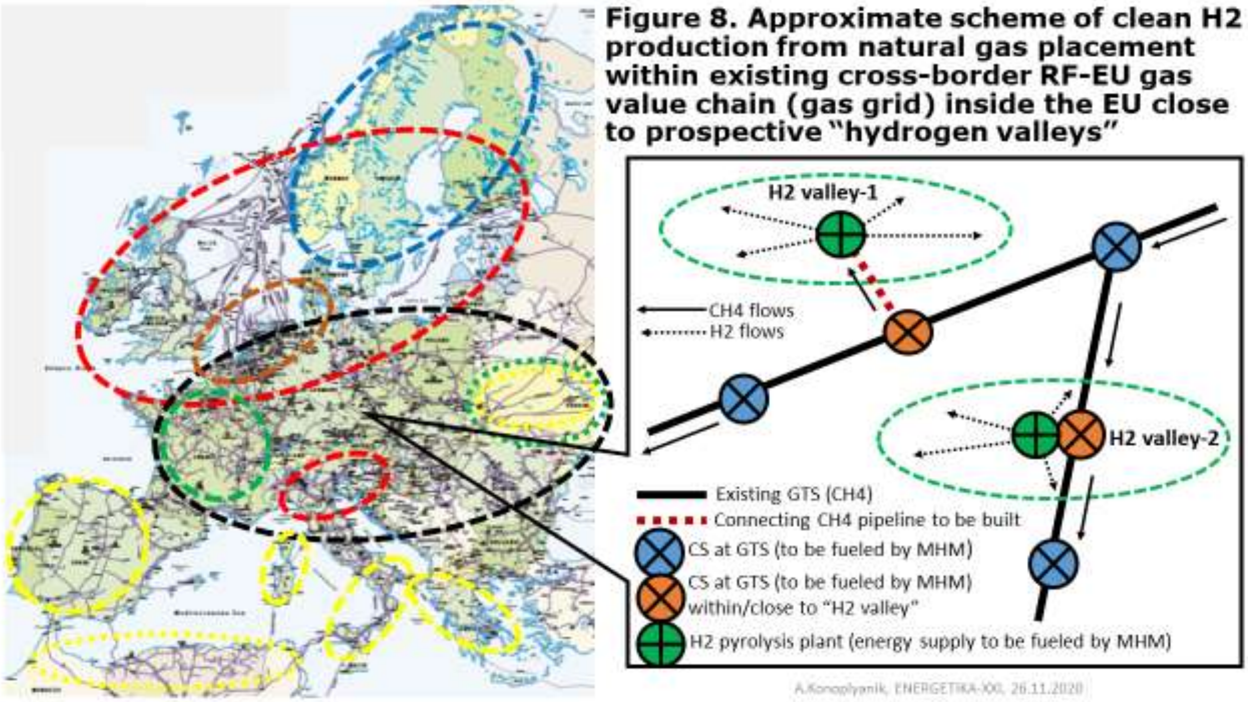


Figure 8. Approximate scheme of clean H2 production from natural gas placement within existing cross-border RF-EU gas value chain (gas grid) inside the EU close to prospective “hydrogen valleys”

Complementarity of H2 production technologies in Europe

Other options for H2 production in Europe will also possess their competitive niches if technology neutral regulation within the EU is provided (geographical areas for their preferential use are presented at **Figure 8**):

---

[12] Dr. Oleg Aksyutin. Future role of gas in the EU: Gazprom’s vision of low-carbon energy future. // Presentation at the 33rd round of Informal Russia-EU Consultations on EU Regulatory Topics (Consultations) & 26th meeting of the EU-Russia Gas Advisory Council’s Work Stream on Internal Market Issues (GAC WS2), Saint-Petersburg, 18.07.2018 (https://minenergo.gov.ru/node/14646)

- renewable H2 from hydro power – mostly within Scandinavian states which are entitles, according to UN classification, as hydro-power states (area circled by blue dashed line);
- renewable H2 from wind energy – first and most in the shallow waters of North Sea, firstly in the offshore areas of North-West Europe (area circled by brown dashed line);
- renewable H2 from solar energy – Iberian Peninsula, south Italy and Balkans, Mediterranean islands (areas circled by yellow dashed line). On top of this EU H2 Strategy assumes that renewable H2 will be produced beyond the EU and be transported then to the EU. In case of H2 from solar energy such production areas beyond the EU mentioned in its H2 Strategy are North Africa and Ukraine (areas circled by yellow dotted line);
- in case of H2 produced with nuclear electricity this can be definitely France (circled by green dashed line) and Ukraine (circled by green dotted line);
- the area for MSR+CCS is definitely the North and Baltic seas and their coastal areas from where CO2 could/would be utilized and transported to depleted oil and gas fields (for sequestration) or to still producing oilfields (to be injected to increase oil recovery).

Green H2 is not a clean H2

Carbon black, a byproduct of methane pyrolysis, is not a climate pollutant, unlike CO_2. Carbon black monetization creates additional revenues in the scheme of pyrolysis production of hydrogen, as opposed to the additional cost of CCS in case of H_2 production by MSR. Both technologies of H_2 production from natural gas are 3-4 times (according to Gazprom[13]) or 10 times (according to BASF[14]) less energy intensive in terms of direct energy consumption compared to H_2 production by electrolysis. Therefore, they require much less installed energy capacity for producing equivalent amounts of H_2.

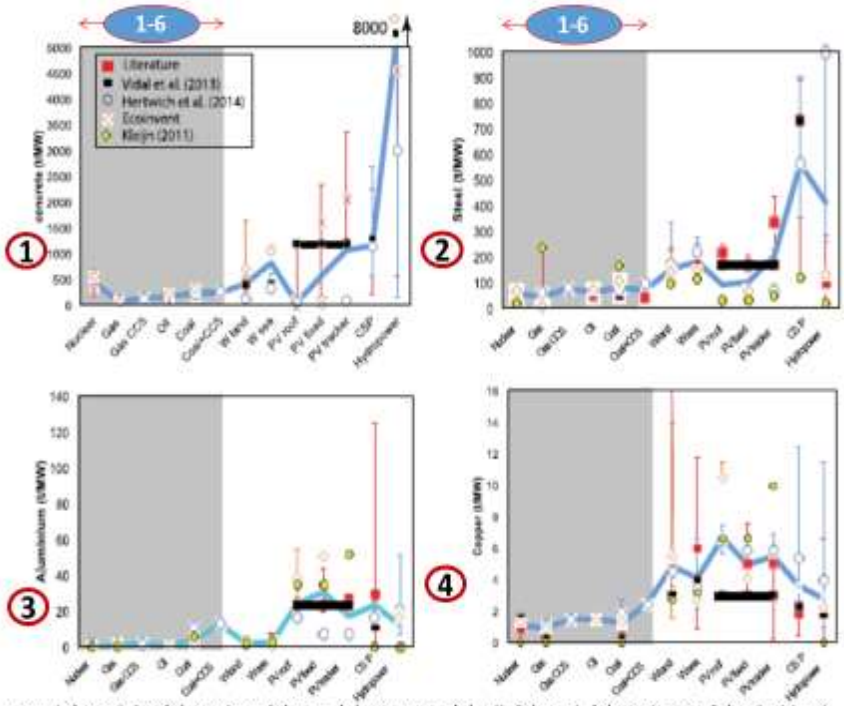
In order to reduce the cost of producing “renewable” H_2 by electrolysis, the EU is advising its companies to use “surplus” RES electricity, which may be available at zero or even negative price. However, this approach may help to reduce the cost of purchasing electricity, but not the cost of creating the RES generating capacities. It has been proven (for example, by Olivier Vidal[15], who performed a study based on four primary construction materials - cement, steel, aluminum, and copper - used in 13 NRES/RES-based power industry technologies) that material intensity of RES power generating capacities is several times higher than that of conventional fossil fuel-based power generation (see **Figures 9-10**).

---

[13] Предложения ПАО «Газпром» в рамках процедуры получения комментариев по «дорожной карте» стратегии Европейского союза в области водорода. Дискуссионный документ. Июнь 2020 г., с. 5 (PJSC GAZPROM’S PROPOSALS for the Roadmap on the EU Hydrogen Strategy, Discussion paper. June 2020, p. 5).

[14] 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)

[15] Olivier Vidal. Mineral Resources and Energy. Future Stakes in Energy Transition. // ISTE Press Ltd - Elsevier Ltd, UK-US, 2018, 156 pp.

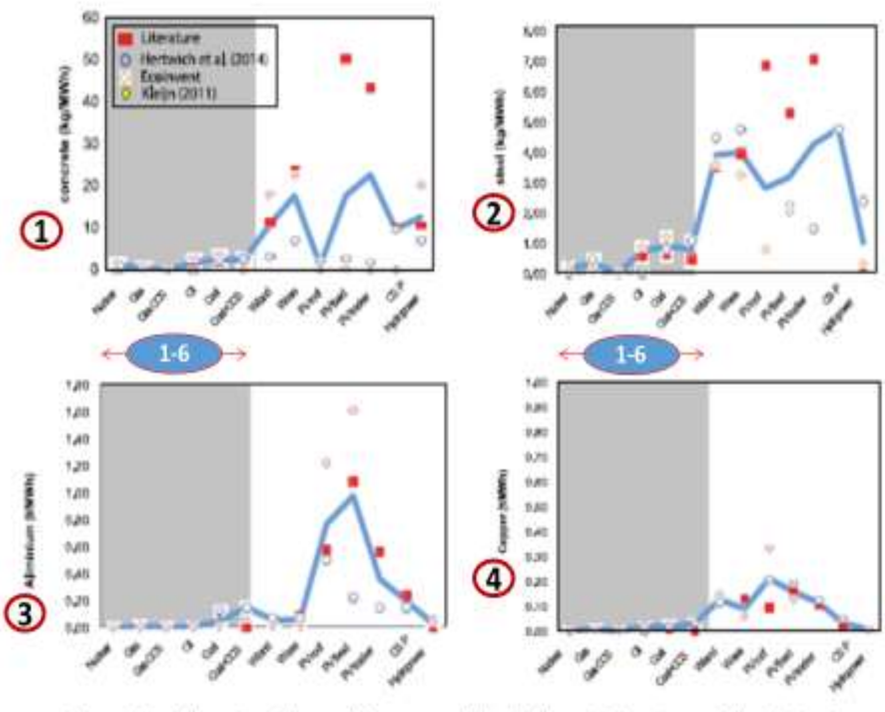


From left to right: (1) Nuclear, (2) Gas, (3) Gas+CCS, (4) Oil, (5) Coal, (6) Coal+CCS, (7) Wind land, (8) Wind sea, (9) PV roof, (10) PV fixed, (11) PV tracker, (12) CSP, (13) Hydropower

Figure 9. 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)

A.Konoplyanik, ENERGETIKA-XXI, 26.11.2020



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

Figure 10. 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)

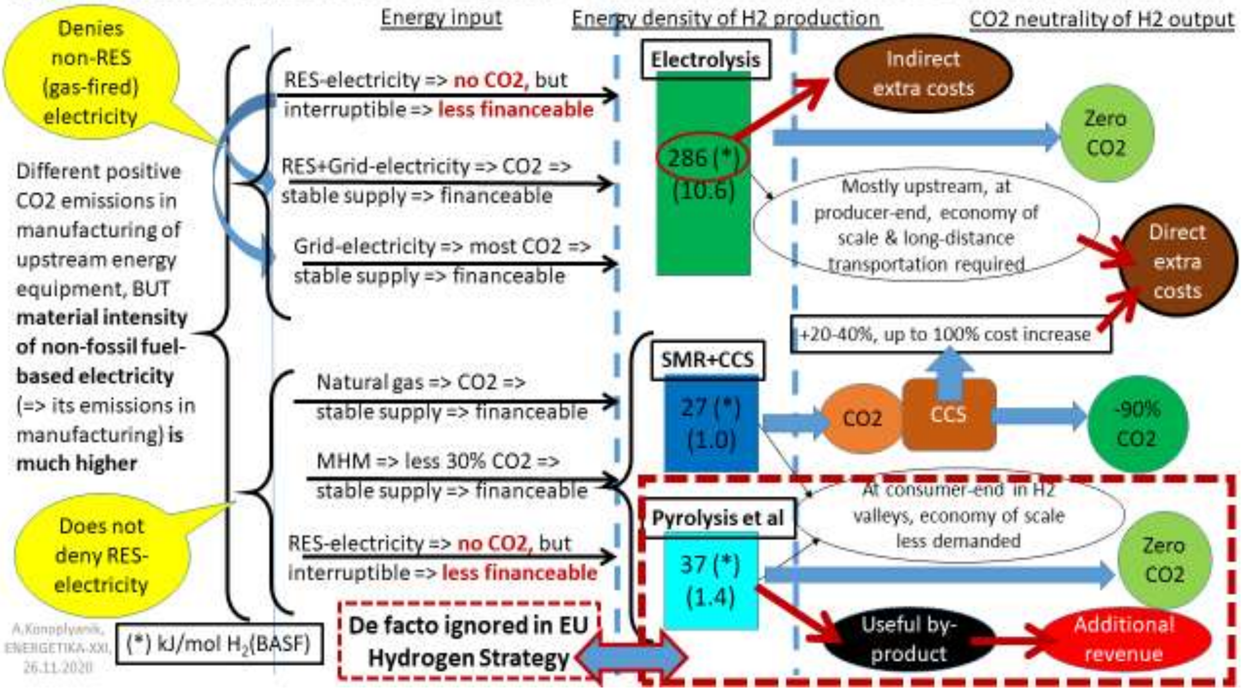
A.Konoplyanik, ENERGETIKA-XXI, 26.11.2020

Therefore, the thesis accepted as a basis in the EU that the only "clean" H_2 is the "renewable" H_2, for which, as stated in the EU Hydrogen Strategy, "greenhouse gas emissions over a full lifecycle are close to zero," loses its meaning. As Dan Yergin has correctly stated: "New supply chains for net-zero carbon requires carbon" (see **Figure 11**).

Figure 11. What is clean energy? Depends on how you calculate/consider it…

Furthermore, the naturally irregular character of solar/wind power generation significantly worsens the conditions for commercial funding of "renewable" H_2 compared to H_2 from natural gas. This means, renewable H2 has lost its perceived absolute dominance as if the only "clean" H2 (this is not the case anymore), so the corridor of competitive opportunities has to be broadened to other sources of H2 production technologies, including from natural gas with the same "clean" results as with electrolysis, i.e. without CO2 emissions in the course of its production (see **Figure 12**). What should matter – is the relative carbon track through the whole energy value chain, to be correctly measured, thus including energy equipment production life cycles.

Figure 12. 3H2: Input-output CO2 options – no totally clean alternative through value chain



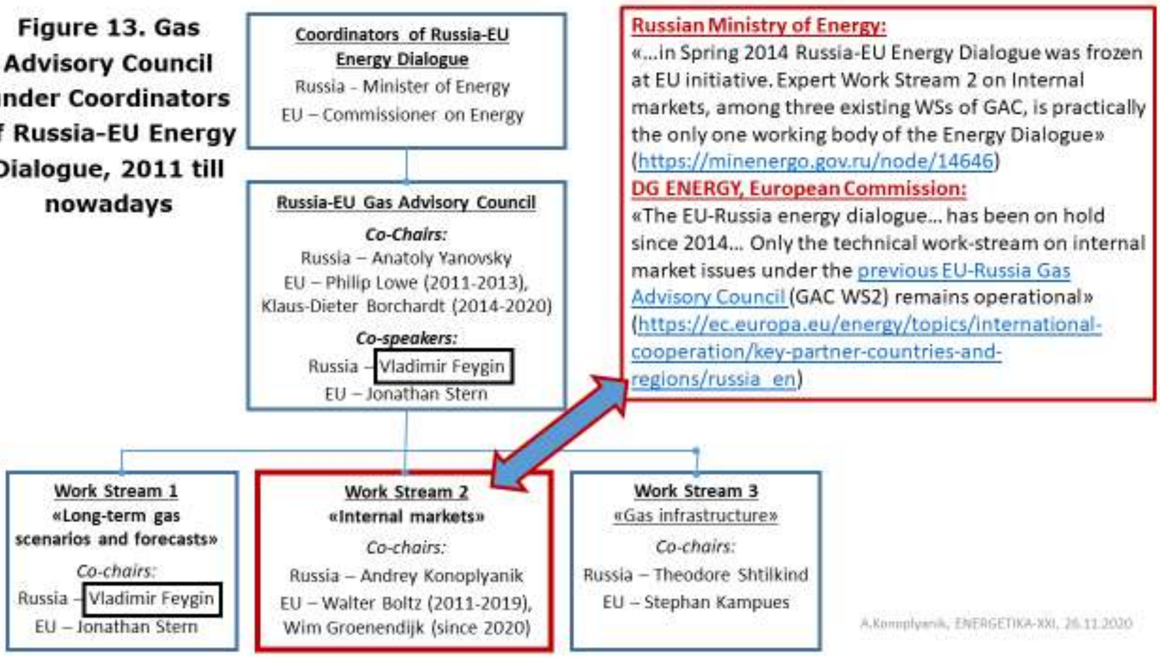
Let's all technologies work

The above proposal leave the open space for complementarity of different H2 production technologies within the EU – each of the three key ones can/will/should find its competitive niche in the "technological mix" based on "technologically neutral" (as was multiply proclaimed in the EU) regulation (see **Figure 8**).

Therefore, in my opinion, the proposed alternative concept not only reflects a balance of interests of the parties, but also is a cheaper tool for the EU to achieve the goals of their decarbonization policy, and will allow Russia to secure a new demand niche in the EU market as part of its participation in the EU decarbonization program — a new market segment of demand for natural gas to be used for producing "clean" H_2 (without direct CO_2 emissions).

We are developing and discussing this concept within Work Stream 2 "Internal Markets" of the EU-Russia Gas Advisory Council (WS2 GAC)[16] which today stays as the only one working body of the Energy Dialogue which remains operational, as stated both at the sites of Russian Ministry of Energy and DG ENERGY of European Commission (see **Figure 13**).

Figure 13. Gas Advisory Council under Coordinators of Russia-EU Energy Dialogue, 2011 till nowadays



The views presented in this article do not necessarily reflect the official position of Gazprom Group and/or Russian authorities and are **the sole responsibility of this author**.

Research is undertaken with financial support of the Russian Foundation for Fundamental Research within project #19-010-00782 "Influence of new technologies on global competition on raw materials markets"

All publications and presentations of this author are available from his website www.konoplyanik.ru.

[16] Work Stream 2 "Internal Markets" of the EU-Russia Gas Advisory Council (WS2 GAC) webpage at the website of the Russian Ministry of Energy: (https://minenergo.gov.ru/node/14646)