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Mosaic Strategy of Carbon Neutrality Incl. On The Example of Fuel Ethanol

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Abstract

The energy transition implies a qualitative change in the structure of primary energy carriers in the world. At some point, there is an increase in the share of new energy carriers from insignificant (less than 3%) to predominant (more than 50%). It is known that two completed energy transitions are currently taking place.
***First:** from natural biofuels to fossil coal in the XIX century.*
***Second:** from fossil coal to oil and natural gas in the XX century. Some authors believe that was two transitions - first to oil, then to gas, but the share of gas reaches less than 25% [1], which does not correspond to the definition of energy transition.*
***Third:** from fossil carbon fuels to environmentally friendly renewable energy sources (i.e., in the future, to carbon neutrality).*

The problem of the third energy transition is its non-spontaneity, unlike the second and the first. Government don't ban firewood in the XIX century and coal in the XX century. There was an increase in energy consumption, and it was saturated by new energy carriers and by new technology of energy production. Old energy carriers and old technologies remain in sectors where they are economically preferable for users. There, substitution is either not took place at all, or took place step-by-step, mosaically, when adapted to the new. For example, coal and external combustion technology remained the leaders in electric power generation [2], but in scattered sectors they were spontaneously replaced by diesel generators.

The third energy transition is dictated administratively, based on the goals and framework of the Paris Agreement, according to the decarbonization plan. The displacement of old energy carriers and technologies is going by rough intervention in the market mechanism, faster than it acceptable for consumers. Market smoothing does not work, and the transition mosaic does not spontaneously occur. It was possible (not to the detriment of the goal) include a mosaic to the plan, but this was not done. The "green turn" plan began to be carried out as a "green fracture", as an economic structure destruction, as a shock.

Societal response to such a shock going by Ibn Khaldun's general rule [3] (more famously, like the Laffer curve [4] in supercritical taxation). Of course, the cause of the recession, the energy crisis, stagflation and autarky are not only the decarbonization plan's mistakes. One way or another, now there is a forced rollback - to the restart of coal energy, to the old nuclear energy strategy and to investing in natural gas logistic. There is likely to be a second attempt at decarbonization, and a mosaic factor may be used to avoid next mistakes.

1. Mosaic principle in economic and energetic systems.

This is followed by the definition of mosaicity (generalized structural diversity of the system).
Mosaicity - this property of the system to contains a large number of autonomous fragments that differ from each other:

- Different genesis
- Different internal composition
- Different cycle of operation
- Different ways of commutation with other fragments

In this case, different workable options for including the same fragment in a large system (commutative diversity) are possible.

In the observed reality, any system, as it grows uniformly or assembles from unified modules, reaches the unification crisis point. Beyond this point, it loses stability and either becomes mosaic or splits.

This is the homogeneity limit rule for unified systems, and should always be taken into account in large-scale economic design. Unfortunately, plans for major reforms are more often based on the bureaucratic ideal of complete unification. This is how the illusion of ease of assembly and control is achieved - but the illusion collapses when it meets reality. Mosaic systems are difficult to assemble and even more difficult to control, but they can work on a large scale (where unified systems cannot).

With regard to energy:
Unified systems are built on rigid hierarchical networks of production and distribution of the basic energy resource used in a unified way.

Mosaic systems are built on multivariate production and different parallel ways of distributing several multifaceted energy intermediates (this ensures freedom of situational energy maneuver).

2. Ethanol as primary energy carrier and as fuel

Below we will analyze one of the possible intermediates that can play a role in the mosaically transition to a carbon neutrality. This is ethanol.

Ethanol is already a large-capacity product that can be produced using at least three well-known "green" technologies:

1. Fermentation of any bio-organic raw materials, followed by distillation.
2. Electrochemical method: from water and carbon dioxide on a catalyst.
3. Controlled chemical oxidation of plastic waste.

At the same time, technologies-1 and -2 are characterized by zero carbon balance in the cycle of production and use (carbon emission during use does not exceed carbon binding during production).

Technology-1 makes it possible to produce ethanol (bioethanol) with minimal artificial energy input. Biomass cultivation can be carried out in artificial conditions with little energy input, or in natural conditions without energy input.

The most promising biological type for cultivation for this purpose seems to be cyanobacteria (photosynthetic prokaryotes). The processes of cultivation of cyanobacteria have been studied in sufficient detail [5]. As it known, cyanobacteria to double their biomass per one day under comfortable natural conditions. Fermentation does not require energy. Distillation requires an energy input of less than 10% of the internal energy of the resulting fuel (concentrated ethanol).

This technological process is interesting in that it produces a primary energy carrier by biotechnology with the absorption of carbon dioxide and does not require arable land (cultivation takes place in an aquatic environment, possibly on fenced water surfaces). Of course, this requires accounting of side effects in environment.

Technology-2 allows the use of ethanol as an energy storage device to smooth out the instability of the output of solar and wind power generators.

To implement this process, it is possible to equip a renewable energy generator - an electrochemical installation for a one-stage process of carbon dioxide binding.

Estimates of the efficiency of such energy storage are 30 - 40%, however, Faradaic efficiency (FE) up to 91% for carbon-supported copper (Cu) catalyst has been reported [6]. For classic batteries, the energy storage efficiency can exceed 70%, but they have their drawbacks.

Ethanol is a natural metabolite of the body and is non-toxic in moderate doses. Ethanol is somewhat less flammable and much less environmentally hazardous than gasoline.

Next, an important property of ethanol should be noted: versatility as fuel. Ethanol easily replaces gasoline in conventional internal combustion engines (including car engines). In practice, this has been verified massively and repeatedly over a period of more than 100 years. The specific heat of combustion of ethanol is 30 MJ/kg, gasoline 42 - 44 MJ/kg.

The wholesale price of ethanol since the 1910s has remained on average close to the price of oil, which fluctuates a lot. At the periods of high price of oil, cars sometimes switched from gasoline to ethanol. 100 years ago, in the agricultural regions of America, massive Ford Model T often ran on bioethanol (more precisely, on farm moonshine). Despite the imperfections of these cars, they had a zero-carbon footprint in terms of mileage. In some countries, ethanol is now being sold as an alternative (along with gasoline) fuel for conventional cars.

In the energy sector of the XXI century, it is extremely important possibility of ethanol using as energy carrier for electro cars. There are several types of fuel cells that implement direct chemical generation of electricity by oxidizing ethanol. Some obstacle is the high cost and chemical vulnerability of catalytic proton exchange membranes for fuel cells. But, as ceramic (oxygen-exchange) membranes develop, this is no longer a critical problem.

3. Ethanol, li-ion, and hydrogen in terms of carbon neutrality

Of course, an ethanol-powered electric car cannot be charged from the electrical grid like a battery-powered electric car. But, on the other hand, the energy intensity of standard li-ion batteries does not exceed 1 MJ/kg. Hence, the extremely unfavorable weight characteristics of battery electric vehicles compared to liquid fuel vehicles, be it gasoline or ethanol. This is a serious problem even for land transport. Even more serious - for water transport. And almost fatal for air transport. If we add here the high price of batteries and toxic components in them, then the benefits of switching to such electric vehicles look doubtful.

Often in the literature, the transition to battery electric vehicles is presented as part of the transition to carbon-neutrality. In fact, these are two different concepts that slightly intersect, and partly even contradict one another (we will return to this later).

When moving, battery electric vehicles consume energy that has already been produced in one way or another, with one or another carbon footprint. Now more than 60% of electricity is generated by burning carbon fuel. When considering losses in power lines (about 10%) and the energy cost of producing battery components, electric vehicles are very far from being carbon neutral.

Note that hydrogen is often considered in the literature as an alternative to lithium batteries. The heat of combustion of hydrogen is 120 MJ/kg. Hydrogen is almost ideal for use in an electrochemical fuel cell (both in its electrolysis production and when used as an energy carrier). In addition, hydrogen is non-toxic and completely environmentally friendly.

The problem of hydrogen is related to the inconvenience of its storage due to its extremely low density. Let's illustrate this in comparison with a conventional fuel tank.

A 40-liter fuel tank weighing 7 kg contains 30.4 kg of gasoline (equivalent to 1300 MJ).
A 40-liter cylinder weighing 60 kg at 300 bar contains 0.8 kg of hydrogen (equivalent to 96 MJ).
The energy/weight character 1.58 J/kg is not so far to 1 J/kg for the lithium battery.
On heavy transport, it is possible to use cryogenic containers with a temperature of 20 K.

A cryogenic tank of 40 liters contains 2.8 kg of liquid hydrogen (equivalent to 336 MJ), however, when calculating the energy/weight character, the weight of the cryogenic installation will have to be taken into account, and in the economic calculation - the very high cost of such an installation become a problem.

Hydrogen is excellent for only one transport niche: hydrogen airships, where volume is not an issue (hydrogen is used there primarily as a carrier gas at normal pressure). The possible revival of the "zeppelin era" is beyond the scope of this article and is a separate discussion topic.

Let's return to ethanol as an intermediate energy carrier. Its energy/weight character is 75% of that of gasoline. This is acceptable for practical purposes. Most importantly, there is no need to build a new large-scale infrastructure for transport on ethanol. It is built into the finished gasoline infrastructure.

Let's note: for transport on lithium batteries and for transport on hydrogen - a new large-scale infrastructure is definitely required.

Thus, it is ethanol that is suitable for the role of an energy carrier in the mosaic scenario of energy transition to carbon-neutrality.

Summary

Before you solve any task, it's need separate this task from other tasks (which seem similar). In this case, the task of transitioning to carbon neutrality should be separated from the other two tasks:

- objectives for the development of environmentally friendly technologies (including transport).
- tasks of organizing ecologically clean territories.

The Paris Agreement of 2015/2016 did not separate these tasks, and an attempt was made to solve that in parallel, by the middle of the XXI century. It was assumed that the economic resources and administrative capabilities is enough. Judging by the interim result of 2022 - it was not enough.

It was created many samples of clean technologies. Also was organized several regions with local renewable energy. (Moreover, this was created not by replacing dirty primary energy technologies, but by deindustrialization, by pushing out dirty technologies to other regions). The transfer of coal technologies, for example, from Scandinavia to Indochina will not change the carbon balance in the atmosphere. In addition, the artificial unified design of decarbonized energy achieved in “clean” regions has proven to be unsustainable (remained dependent on fossil fuels), as is clear from the energy crisis that began in 2021.

Now requires an approximate analysis of the global production and consumption of primary energy in physical (not financial) terms. The next step will be to select a few convenient energy intermediates for the carbon neutral cycle (ethanol is a typical example of such an intermediate). After that, the task is reduced to covering key positions on the Global market of primary energy carriers by such intermediates.

The importance of the mosaic principle should be emphasized. The displacement of fossil energy carriers by carbon neutral energy carriers - should go where it is obtained by direct competition in terms of price and quality. In a different way (by non-market methods) it has already tried - and the current state of affairs shows that this did not lead to a good result. Rational movement step by step suggests the best result.

As shown above, ethanol could cover key positions in the light oil market - without the huge cost of changing consumer devices (including without replacing ICE-cars to electric cars).

If the Paris Process had been oriented from the very beginning to the replacement of primary energy, and not to the “climate coercion” of final consumers, then perhaps now the intermediate result would have been much more optimistic.

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