Barriers disturbing development of innovative measures for mitigating climate change

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According to SPM of IPCC AR-5 WG1\(^{(1)}\) cumulative (anthropogenic) emissions of CO\(_2\) and global mean surface temperature response are approximately linearly related. It indicates that stabilization of the global surface temperature requires almost zero emission of CO\(_2\). Considering that more than 85% of primary energy mankind depend upon are fossil fuels, we mankind are required to make drastic efforts for decarbonization in the coming future.

There are various measures for decarbonization of energy, but we see in most of them barriers seriously disturbing their development and propagation in the society. Let me show you just two examples of this kind.

1. CCS(CO\(_2\) Capture and Storage)
   —how do we improve the public acceptance?—

   One of the famous scenarios of the decarbonized world in future is the blue map scenario developed by IEA\(^{(2)}\). It tells that realization of halving the global CO\(_2\) emission by 2050 requires to reduce about three forth of the emission in 2050 in BAU(business as usual) scenario, and about one third of the reduction is by implementation of CCS. By installing CCS at fossil fuel fired power plants we can realize zero emission power plants in spite of burning fossil fuels. Therefore many countries plan to introduce CCS to power sector in the near future. According to GCCSI survey\(^{(3)}\) over the world, however, there have been no power plants which introduced CCS until now and only two new power plants in North America will start their operation with CCS this year for the first time in the world. Importance of introducing CCS into power plants being broadly recognized as in IEA scenario, why is the real action so slow?

   The basic reason is not technological but economical and societal. First, the cost of CCS is expensive at the moment, more than several tens US dollars per ton CO\(_2\) disposed, mainly due to high cost of capturing CO\(_2\) from flue gas of power plants. I am convinced that we
will be able to clear this economic barrier by technological efforts eventually but a little more time will be needed for this.

Secondly, introduction of CCS requires its acceptance by the residents around the storage site. Most scientists related to CCS technology believe they can manage transportation and storage of CO2 safely, but reaction of residents are different from that of these scientists. Most of them are sensitive to leakage of CO2 particularly from huge storage sites connected to large scale power plants.

Therefore we need to establish the strategy so that residents may believe CCS is sufficiently safe. This is the first but the most important step we should take for realizing the scenario like IEA blue map scenario.

2. Automobile fuels
—how can mankind decarbonize automobile fuels?—

Typical answers expected to this question may be to introduce (a) battery driven electric cars (EV), or (b) fuel cell driven cars (FCV). Both of them emit neither CO2 nor flue gases at all in operation. However both electricity and hydrogen are secondary energy. At least at present primary energy sources of electricity and hydrogen include fossil fuels which are sources of CO2 emission.

As for electricity we have been already doing efforts for reducing carbon content of electricity by introducing renewables, increasing the share of nuclear power, and reducing carbon content of fossil fuels by reducing coal and increasing natural gas. Introduction of CCS as described in 1 is certainly another effective means for reducing carbon content of electricity.

Then how about hydrogen for fuel cells? Toyota, the largest automobile company in the world, already announced to start sales of FCV from the latter part of this fiscal year. At present hydrogen is produced from chemical decomposition of fossil fuels or from electrolysis of water of which the energy comes from electricity. If our target is to realize completely decarbonized society in future the former way of producing hydrogen is clearly to be avoided. (If we add CCS in this process we can realize hydrogen production without CO2 emission. However, since we already discussed on difficulties of implementing CCS, we exclude this process in the present discussion)

Then how about the latter way? If we will make a success in realizing
complete decarbonization of electric power as described above, then hydrogen produced in the latter way may be called carbon free hydrogen.

However even in this case we have another problem about FCV. The figure shown below is the flow of energy in the case of FCV with electric power as the source of hydrogen (upper FCV path) and that of the case of EV (lower EV path). For both paths the energy source is electric power and the final energy driving the motor is again electric power. Then the total efficiency of the FCV path is $h_1h_2$, where $h_1$ is the efficiency of electrolysis of water and $h_2$ is the efficiency of fuel cells. In contrast to the upper FCV path in the figure we can have another path from electric power to driver motor which is the lower path, i.e. EV path. The total efficiency of this path is as seen in the figure just $h_b$. The theoretical conversion efficiency of fuel cells is $83\%^{(4)}$ but the efficiency of actual fuel cells is still of the order of 50 to 60% at maximum, while the battery efficiency is in most cases more than $85\%^{(5)}$. Therefore the total efficiency of the upper path (FCV path) $h_1h_2$ is clearly lower than that of the lower path (EV path) $h_b$. It indicates that EV is more efficient than FCV, as long as we utilize electricity as the source of hydrogen.

Then is there any way of converting non carbon energy directly to hydrogen? One possibility is direct conversion of solar power to hydrogen by photo catalysis. There have been a lot of studies on this since the discovery of this process by Honda and Fujishima$^{(6)}$, but the conversion efficiency ever attained is still around 1% or less, very low.

Therefore if we want to utilize FCV in the future decarbonized society we should try to develop innovative technology to produce hydrogen from renewables with much higher efficiency than that of the presently available technology, or utilize fossil fuels as primary
energy with complete CCS. Both ways are however not so easy to achieve. Then what direction do we select for future decarbonized fuels for automobiles?

We can pile up the above type of discussions on other measures for decarbonization and find barriers disturbing their development. I earnestly hope that related scientists and engineers will make much efforts for clearing these barriers.

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