Public Workshop to Discuss Opportunities for Additional Greenhouse Gas Reductions from Petroleum Transportation Fuels

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Even the most rapid energy transitions we can envision have liquid fuels playing a role in our economy for several decades to come. How can we make those as low carbon as possible? At Lawrence Livermore Lab we believe it is possible to significantly reduce California's transportation carbon emissions, while protecting jobs and improving air quality, by using carbon capture and storage to reduce the carbon intensity of California oil production. We can use the State's oil industry to store CO_2 that is removed both from their operations, and from the air.

Lawrence Livermore focuses on financially feasible ways to reduce carbon dioxide emissions. Even after we have electrified everything we can, we will still need to withdraw CO_2 from the atmosphere because we have already emitted too much. We call this 'negative emissions'. The low carbon fuel standard is an important mechanism to motivate the development of technology and businesses required to achieve negative emissions. The California oil industry is a prime source for realizing significant volumes because they have the infrastructure, resources and desire to do this important work.

The Central Valley is a promising region for taking this on in California. We imagine the oil industry in the region transforming from emitting carbon, to absorbing carbon dioxide. The trained workforce and existing business frameworks make it reasonable for California's oil industry to make this transition and become a world leader not just in reducing their own carbon dioxide emissions, but ultimately removing it from the atmosphere. Eliminating the California oil industry removes that option.

This opportunity comes from two main activities. First, the oil industry can reduce its emissions by capturing CO_2 produced both on the oil fields, and in refineries, and put that CO_2 underground as included in proposed revision to the LCFS. The oil industry is almost perfectly configured for this activity – it has the tools, the experienced workforce, the proper land, and the knowledge of the subsurface conditions. When CO_2 is pumped deep underground it behaves very similarly to oil. That makes oil reservoirs, or the rocks under reservoirs, a safe place to consider storing CO_2 because those rocks have retained oil for millions of years. To date the US has conducted tests of this technology that have put 14 million tons of CO2 safely

and permanently underground. Worldwide there are 20 projects in operation, gaining experience and contributing to international engineering standards.

Our analysis indicates that any LCFS price above $100/ton will result in significant adoption of underground storage of CO_2 in California. With 16 million tons of emissions on field, and 35 million tons from refineries, the oil industry's CO_2 provides a large target. Changing to renewable energy sources in oil fields is also a terrific way to reduce the carbon footprint and is also incentivized by the revised LCFS.

Second and perhaps most exciting, there is an opportunity to combine better biofuel production with CO_2 storage in or under California's oil fields. Typical biofuel production, such as ethanol fermentation, releases one atom of carbon dioxide for each atom of carbon that ends up in the fuel. While this CO_2 originally came from the air and is not counted against the fuel's carbon footprint, *capturing that CO_2 and putting it underground would directly address atmospheric CO_2 levels.* This CO_2 is especially easy to catch from ethanol and biogas plants. CO_2 from other biofuel production approaches such as gasification or pyrolysis can also be captured with no more difficulty than flue gas. California currently produces on the order of 38 million tons of biomass annually which could be converted to biofuel (making roughly same number of barrels of fuel). This would produce another 38 million tons of storable CO_2, effectively removed from the atmosphere. Of course, the full lifecycle of these processes must be considered.

What are the limitations to these approaches? First, safe storage sites must be established. We believe that California's Central Valley could have many of these sites. Second, the CO_2 from the various fuel-producing activities must be accumulated and moved to designated storage sites. In the long run, doing this with pipelines would be ideal, but in the interim rail transport makes sense. Railways in the Central Valley are well situated for both the sources and likely storage sites. $100/ton LCFS prices will provide sufficient economic incentive including capturing CO_2 from the sources.

Finally, the complex regulatory environment must be clarified for businesses interested in creating this new system of carbon reduction. This includes specifying who the State and federal agencies with primary authority are. Today the federal EPA, CARB, and the Department of Conservation all have key authorities for the underground storage. A simplifying measure for California would be to seek primacy for the EPA Class 6 well standards that control underground storage of CO_2, keeping all the regulatory approvals required in State hands. We must also consider the important issue of CO_2 transportation and its regulation. The State could convene a discussion of regulatory issues in carbon capture and storage.

An important consideration is air pollution other than CO_2. In general, carbon capture facilities reduce criteria pollutants from combustion sources, such as biomass-fired power, because the CO_2 capture systems also remove SOx and NOx. However, the need to accumulate CO_2 from a number of small sources (typical biofuel refineries emit 50,000 tons of CO_2 annually) could generate transportation emissions if not done efficiently. The transportation issue warrants close attention in any systematic study of the opportunity carbon capture and storage presents for California.

In the long run, the only place to store the carbon we need to remove from today's overpolluted atmosphere is underground. California can enable this atmospheric reduction by establishing carbon storage sites. The State has the capacity to store more than 100 billion tons of CO_2 – an impressive amount by any accounting. Safe Central Valley storage sites can be profitably established today to reduce the overall carbon footprint of the State's transportation industry. In the future when we achieve carbon-free power and transportation, those sites can continue to store atmospheric carbon dioxide from biofuel production or from facilities that directly capture carbon dioxide from the atmosphere.

Lawrence Livermore's discussions with the California oil industry indicate that there are many groups and corporations eager to adopt carbon capture and storage in association with oil and biofuel operations. When we first began talking with these groups it seemed that putting the CO_2 into producing oil fields might be the favored approach, and this still might be an important technique. But it may be more advantageous to create centralized storage facilities. These would entail single new, permitted wells, that put CO_2 into abandoned fields or into the non-producing rocks around or below oil fields. They would likely be owned and most importantly, *well understood* by oil concerns. The infrastructure of this approach is simple and stored CO_2 is readily verified.

These CO_2 storage facilities would take advantage of multiple sources of CO_2 from the California fuel cycle. Once the (not insignificant) capital investment of the storage facility is made, incremental additions of capacity, such as from a new biogas fermenter, are easy to make. It is feasible given the potential scale of the fuel cycle sources (about 80 million tons of CO_2 with full build out of biofuel potential), that California's current transportation emissions could be reduced by ½.

On the way to a fully electrified future, this approach could remove the remaining CO_2 emissions in a much shorter time frame than currently envisioned and could do so while maintaining California jobs and the safety of neighboring communities. The last petroleum used by an almost-fully electrified California could be carbon neutral and produced inside the State.

In summary, I believe that a policy of encouraging carbon capture and storage by the State's oil industry as a means to reduce the State's transportation emissions would give us carbon reductions over which the State has strong control, and for which the State can be assured of a good outcome.

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