Problems of Pore Space

Pennsylvanians are again at risk of entering into dangerous leases of their land for an industrial process that they do not understand. This time the landmen want to lease the right to inject carbon dioxide (CO_2) into pore space thousands of feet underground. Underground pore space is empty areas within the subsurface geology where CO_2 can be stored and trapped beneath a caprock.

Senate Bill 831, the Carbon Capture and Sequestration Act, has passed from the PA Senate Committee on Environmental Resources and Energy to the Committee on Consumer Protection, Technology and Utilities in the PA House of Representatives. The consumers, in particular, the residents of Pennsylvania, do need protection from physical dangers and eminent domain, in the form of forced pooling. The process of carbon sequestration, delivering huge volumes of CO_2 by pipeline, or perhaps endless lines of trucks, and drilling of multiple wells to receive CO_2 and to monitor pressures and provide emergency alternative storage, is highly likely to decrease property values and and could negatively impact water and timber resources. Every pipeline produces soil compaction above and this decreases agricultural yield in that space, perhaps by as much as 30%. Geologic carbon sequestration (CS) is a highly technical industry closely related to extraction of fossil gas, in part because as much as 15% of the gas extracted with fossil fuel is carbon dioxide which must be removed and preferably stored. But CS differs from extraction because pumping supercritical CO_2 gel underground can alter subsurface structures in unpredictable ways. There is accumulating evidence that it is very difficult to predict the size and location of the injected mass of CO_2, the plume, (https://jpt.spe.org/irregular-is-whats-regular-for-co2-storage-plumes). Those companies that cite decades of experience in CO_2 injection underground have been cycling just enough CO_2 through a reservoir to enhance recovery of Fossil Fuels. Injecting as much CO_2 as possible for permanent storage is a very different matter.

In Bill 831, lines 6 through 9 on page 2 contain dangerous oversimplifications. It is not reasonable or beneficial to use any subsurface strata . . . for geologic storage of carbon dioxide. Consider the 3 failures of CCS experienced by Equinor (https://ieefa.org/resources/norways-sleipner-and-snohvit-ccs-industry-models-or-cautionary-tales). Seismic studies must identify a large solid caprock that could constraint sequestered carbon

dioxide as it migrates upward. At the site in Algeria (ibid) where Equinor injected carbon dioxide, the upward migration of CO2 deformed the surface of the land. This could seriously damage built structures. When this complication was recognized the carbon dioxide was vented to the atmosphere. At another site, under the North Sea, CO2 migrated upward to a site between strata that had not been recognized on seismic studies. There and at a third site injection was halted because pressures rose beyond what was expected to be retained by the caprock. These sites are mentioned in the 2009 report of the Geologic Carbon Sequestration Opportunities in Pennsylvania, without acknowledgement of the limitations that were later identified. If the caprock cracked and CO2 escaped to the atmosphere it could expand rapidly into low lying areas, diluting oxygen to asphyxiating levels. Less than 10 minutes of lack of oxygen is enough to produce permanent brain damage or death in a human being and other animals that require oxygen to live.

Another illustration of the fact that just any site is not suitable for CS is that injection of large volumes of CO2 into the commonly found brittle rocks can trigger earth quakes. Even small earthquakes can crack the caprock expected to contain CO2 (Earthquake triggering and large-scale geologic storage of carbon dioxide | PNAS). Pore pressure diffusion generated by carbon dioxide injected underground at a carbon storage site in the Illinois Basin is the likely cause of hundreds of microearthquakes that took place at the site between 2011 and 2012, (Josimar A. Silva, Mansour Khosravi, Hongkyu Yoon, Michael Fehler, Scott Frailey, Ruben Juanes. Mechanisms for Microseismicity Occurrence Due to CO2 Injection at Decatur, Illinois: A Coupled Multiphase Flow and Geomechanics Perspective. *Bulletin of the Seismological Society of America*, 2024; DOI: 10.1785/0120230160).

Indeed the 2009 report, titled Geologic Carbon Sequestration Opportunities in Pennsylvania (https://elibrary.dcnr.pa.gov/GetDocument?docId=1743511&DocName=Geologic-Carbon-Sequestration-Opportunities-in-PA-2009.pdf) states, on page 17, that “The largest, single problem for sequestering CO2 in the Oriskany Sandstone is related to cap rock seal failure. Problems with seal integrity would be more likely to occur in those areas where structural deformation of the Oriskany and adjacent rock units is known (particularly along the Allegheny Front). . . .viability of these sandstone reservoirs [Upper Devonian in SWPA] for geologic sequestration of CO2 is also restricted by the unknown integrity of post-production [gas extraction] cap rock and the large number of oil-and-gas wells (active,

abandoned, and orphaned) that could pose risk for CO2 migration and leakage.” Study of possible carbon sequestration sites in Pennsylvania has been ongoing for at least 15 years. The need to protect residents from CO2 leaks from sequestration sites and leaks from the necessary pipelines that would transfer CO2 to these sites has not been widely discussed during those years. Infrastructure buildout for CS must not occur without the awareness of the residents of Pennsylvania regarding the location of all pipelines carrying CO2 and the location of all class VI wells. Because of the long history of abandonment of wells in Pennsylvania, residents must be involved in every permitting proposal so that they can share their knowledge of the local wells of which PA-DEP has no records.

On page 5 of SB 831 there is discussion of the relative priorities of subsurface uses between mineral, including coal, or oil and gas and pore space. On page 50 of the report on Geologic Sequestration Opportunities in Pennsylvania it is stated that in Pennsylvania owners of the surface do not necessarily own the mineral, oil or gas rights under their property. This is a problem for obtaining rights to pore space. Team Pennsylvania, and individuals who have explored the history of laws pertaining to leases of subsurface rights to extracted substances, claim that ’The American Rule’ applies in Pennsylvania. The American Rule asserts that the owner of the surface holds rights to the spaces above and below. The old saying was from Heaven to Hell. The American Rule has been recommended by the Interstate Oil and Gas Compact Commission and is the law in California, Louisiana, Michigan, Montana, New Mexico, New York, Oklahoma, Texas, and West Virginia. SB 831 is designed to undermine the control of the owner of the surface. This is important for carbon sequestration (CS) because it is difficult if not impossible to determine prior to completion of injection the physical extent of the plume of CO2 injected. The extent of the plume after injection is completed could change following earthquakes. The effects of failed CS can have significant negative effects on those living on the surface above, ranging from disruption of the level of the surface, to negative impacts on ground water, and damage to plants and oxygen breathing animals on the surface.

Furthermore SB 831 is compromising the independence of Pennsylvanians, relative to those in neighboring states, by requiring that only 60% of those living above the potential site of a carbon dioxide reservoir need to agree to sell their rights to the pore space, to allow a proposed project to go forward. Sequestration of carbon dioxide

underground will resulting a spreading plume of CO2 the extent of which may be difficult to predict. Other states developing these rules, such as West Virginia, have required 75% of the owners of surface land to agree to sell their rights to pore space before imposing eminent domain on the remaining 25%.

A 2022 paper titled, “Why CCS is not like reverse gas engineering,” (First Break. Why CCS is not like reverse gas engineering. Ringrose et al. Volume 40. October 2022, p. 85-91) jointly published by a team of Norwegian scientists, including some of Equinor’s most prominent geophysicists, provides a useful discussion of the issues. The paper clearly states many possible unknowns may be encountered and changes may occur over the life of a field in which carbon dioxide is sequestered– and beyond. Pennsylvanians must not be left to repair the damage produced by this industrial activity. The industry must post greater bonds than previously imagined because the potential damage is greater and the duration of instability of the injected CO2 may be at least hundreds of years. Therefore the utility of depositing CO2 into pore space in order to reduce atmospheric CO2 is very questionable.