Liane Randolph
Chair, California Air Resources Board
1001 I St
Sacramento
CA 95814

Re: Public Workshop Series to Commence Development of the 2022 Scoping Plan Update to Achieve Carbon Neutrality by 2045

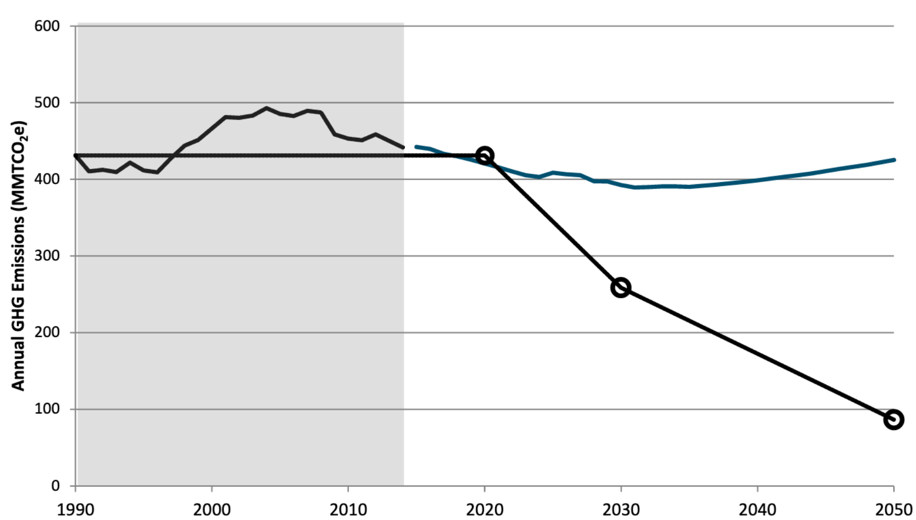
July 8th, 2021

Dear Chair Randolph,

The undersigned thank you for the opportunity to comment on the opening workshop of the 2022 Scoping Plan Update of June 8-10, 2021, by the California Air Resources Board (CARB). We represent a diverse set of stakeholders from industrial, environmental, labor and research sectors. We are tracking this Scoping Plan update process with great interest, as it is the most ambitious and challenging one yet, in light of the state's mid-century climate goals. We offer the comments below on a small number of topics that were brought up during the opening workshop for the update process.

California can only achieve its mid-century goals if it both intensifies existing efforts and expands its climate toolkit

California has made notable progress in decarbonizing its economy the past two decades. This progress, combined with economic downturns beyond its control, has enabled the state to meet its climate goals to date. However, as the figure below from CARB's Overview Presentation from Day 1 of the June, 2021 workshop shows, the bulk of the work still lies ahead:



Illustrative example of Reference Scenario and GHG Mitigation targets

We are united in believing that achieving carbon neutrality no later than 2045 and maintaining negative emissions thereafter will require new strategies in the state's portfolio that go beyond what has been done to date: strategies that can drastically reduce or eliminate emissions from large point sources that do not have many other cost-effective decarbonization options (carbon capture and storage (CCS) technologies), strategies that can negate any remaining greenhouse gas emissions that cannot be eliminated, and strategies to remove CO_2 from the atmosphere (carbon dioxide removal, or CDR, technologies).

The exact mix of traditional mitigation efforts and CCS or CDR efforts is not, and cannot, be known at this point. But multiple analyses at the international,[1,2] national and state level concur that CCS/CDR will be necessary to meet mid-century climate goals and the importance of these technologies rises with the ambition of mitigation scenarios. For California, this means 10s of millions of tons CO_2/yr captured or removed and permanently stored, and this number could be upward of 100 million tons CO_2/yr to account for shortcomings in other mitigation strategies and limitations to conventional decarbonization approaches.[3,4,5,6,7] For example, industrial processes such as limestone calcination would still emit carbon dioxide even if they are powered by clean energy sources. Analyses by state agencies presented during the workshop show internal combustion vehicles on the road beyond 2045. The aviation sector appears hard to electrify at this point. And maintaining a small amount of firm, zero-carbon, electricity capacity enables the goals of SB100 to be met at a far lower cost while materially increasing grid stability and reliability.[8]

California can no longer afford to think about reducing its emissions only, but also needs to enhance its carbon sinks, both natural and engineered. Ensuring that these solutions can contribute at the scale of several 10s of millions of tons of CO_2 annually by mid-century is a substantial undertaking that needs to begin today. A large suite of interventions and technologies are available today, but they face scale-up, permitting and economic challenges,

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[1] IEA (2020), CCUS in Clean Energy Transitions, IEA, Paris. https://www.iea.org/reports/ccus-in-clean-energy-transitions

[2] IEA (2021), Net Zero by 2050, IEA, Paris. https://www.iea.org/reports/net-zero-by-2050

[3] E3, "Achieving Carbon Neutrality in California: PATHWAYS Scenarios Developed for the California Air Resources Board", October, 2020. https://ww2.arb.ca.gov/sites/default/files/2020-10/e3_cn_final_report_oct2020_0.pdf

[4] S. Baker et al., "Getting to Neutral: Options for Negative Carbon Emissions in California." Lawrence Livermore National Laboratory, August 2020. https://www-gs.llnl.gov/content/assets/docs/energy/Getting_to_Neutral.pdf

[5] Energy Futures Initiatives and Stanford University "An Action Plan for Carbon Capture and Storage in California: Opportunities, Challenges, and Solutions." October 2020. https://static1.squarespace.com/static/58ec123cb3db2bd94e057628/t/5f96e219d9d9d55660fbdc43/1603723821961/EFI-Stanford-CA-CCS-FULL-rev1.vF-10.25.20.pdf

[6] Eric Larson et al., "Net-Zero America: Potential Pathways, Infrastructure and Impacts", Princeton University, December 15, 2020. https://netzeroamerica.princeton.edu/img/Princeton_NZA_Interim_Report_15_Dec_2020_FINAL.pdf

[7] Williams, J. H., et al., "Carbon-neutral Pathways for the United States." *AGU Advances* 2:1, January 2021. https://agupubs.onlinelibrary.wiley.com/doi/pdf/10.1029/2020AV000284

[8] E3, "Long-Run Resource Adequacy under Deep Decarbonization Pathways for California", June, 2019. https://www.ethree.com/wp-content/uploads/2019/06/E3_Long_Run_Resource_Adequacy_CA_Deep-Decarbonization_Final.pdf

much like the renewable energy technologies that are ubiquitous today faced in the 1990s, earlier in their deployment stage. This requires planning and coordinated state government action, and we urge CARB to incorporate these dimensions in the current Scoping Plan update.

Capturing carbon can also decrease non-CO_2 air emissions and help improve air quality

Adding carbon capture to existing industrial sources can decrease conventional air pollutant emissions. This is an area that has not received sufficient study or dissemination to date, and which we believe is important for California's climate discussions. We are happy to report that such studies will be made public in the coming months.

For example, in the context of what is likely to be one of the most commonly-used carbon capture technologies - amine scrubbers used to remove CO_2 from flue gases - air quality improvements can likely be expected because certain air pollutants degrade the amine solvents. Capture units often add pretreatment steps or upgrade existing controls as a cost-saving measure to protect the amine solvent from degradation. For example, if an industrial source emits sulfur dioxide (SO_2), the SO_2 emissions from adding carbon capture fall to near zero. Either the polishing scrubber added to protect the amine removes the SO_2, or what little reaches the capture unit is removed by the amine.

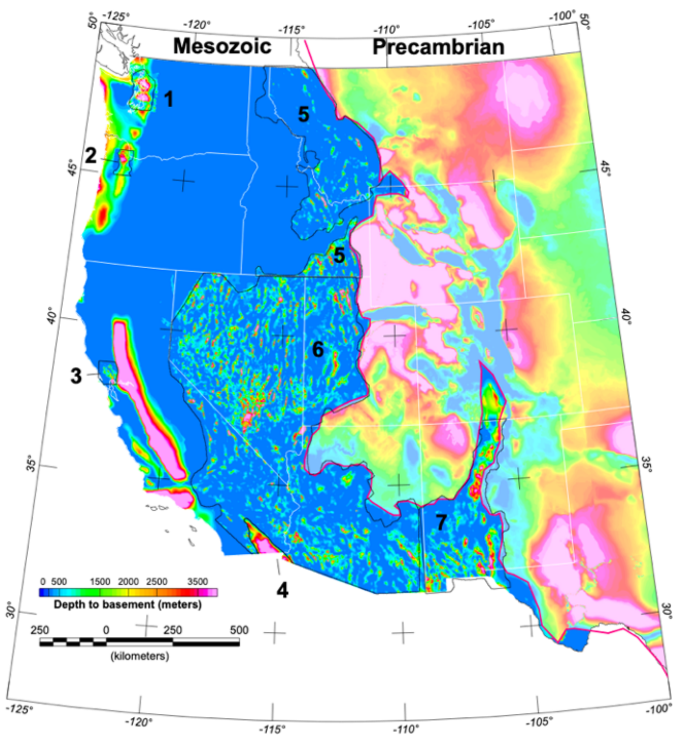
Emissions of particulate matter also decrease, but the degree is application-specific.

Nitrogen oxide (NO_X) emissions are more complex. NO_x is a general term for nitric oxide (NO) and nitrogen dioxide (NO_2). NO does not react with the amine and so is not captured by the amine. NO_2 (which is generally less than 10% of total NO_x emissions, but can be considerably more) is water-soluble and reacts with the amine solvent. Like SO_2, carbon capture projects will generally reduce NO_2 either because the pretreatment added to protect the amine reduces the NO_2 or what little NO_2 reaches the capture unit is reduced by the amine. However, the extra fuel burned to run the capture unit can offset this reduction and could potentially increase total NO_x emissions. The impact is plant-specific and depends on the degree of NO_x emissions in the initial plant, the source of power and electricity for the capture unit, and whether the source upgrades the NOx controls when CCS is added to the plant.

VOC emissions can, in theory, rise from adding CCS to a plant because some amine is lost from the top of the capture unit's absorber. However, this can be kept at very low levels. At the Petra Nova coal-fired power plant CCS demonstration project, additional VOC emissions were small and well below permitted levels.

California is fortunate to have ample, world-class geologic storage sites that can help it achieve net-negative emissions

California's geology - primarily in the Central Valley - features numerous deep sedimentary basins with young, porous rocks that have ample CO_2 storage capacity, and which are often overlain by multiple sealing rock layers that trap the CO_2 safely and permanently. This situation is unique across California and its immediate neighbors, including Idaho and Washington. The figure below by the U.S. Geological Survey shows depth to basement rock, which is a proxy for the presence of these suitable basins.[9]



The U.S. Department of Energy has estimated a storage potential of 4.85 $GtCO_2$ in oil and gas reservoirs in California, and an estimated 30-417 $GtCO_2$ of storage potential in saline formations.[10] This translates into potentially storing hundreds of years' worth of California's total emissions at today's levels safely and permanently (in practice, these emissions will decrease, and only a fraction of them needs to be stored, which amplifies the available storage further).

In short, California has more storage options than it needs to remove CO_2 from the atmosphere and safely and permanently store it thousands of feet underground.

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[9] U.S. Geological Survey, "Depth to Basement and Thickness of Unconsolidated Sediments for the Western United States—Initial Estimates for Layers of the U.S. Geological Survey National Crustal Model", Open-File Report 2018–1115. https://pubs.usgs.gov/of/2018/1115/ofr20181115.pdf
[10] U.S. Department of Energy, National Energy Technology Laboratory, Carbon Storage Atlas, 5th ed., 2015. https://www.netl.doe.gov/sites/default/files/2018-10/ATLAS-V-2015.pdf

The durability of geologically stored carbon from engineered solutions offers a distinct advantage and a guarantee for effective, permanent removals

Removing carbon dioxide from the atmosphere is only part of the challenge; it also has to remain stored/removed from the atmosphere for an extended period of time. The relative permanence of different carbon dioxide removal options - i.e., how easily removal/storage gains might be reversed - is thus of great relevance to achieving carbon neutrality by 2045 in California.

While nature-based solutions increase the biological uptake of carbon dioxide by increasing natural "sinks" or improving natural processes and practices, the uptake rate starts to slow down in some approaches or cases as these processes get closer to maturity. Some, once they reach their saturation level in terms of carbon dioxide, may no longer result in net carbon removal. Moreover, there is always a concern over the degradation or destruction of natural sinks such as forests due to natural or human disturbances. Fires, in particular, which are a prime concern in California, can release much of the carbon that has been stored.

On the other hand, technological solutions store the carbon dioxide permanently in dedicated geological reservoirs after capturing it. Decades of experience with geologic storage have demonstrated that injected carbon dioxide can be safely stored at suitable sites, essentially in perpetuity, with minimal risk of release.[11,12,13]

Cost estimates for CCS technologies are available from several sources

Despite assertions to the contrary in the SB 100 report, several published cost estimates are available for a variety of CCS technologies and industries, some of which are specific to California.

For example, a recent Stanford/Energy Futures Initiative (EFI) study published in October of 2020 provides detailed cost estimates for potential industrial CCS projects in California.[14] The table below shows opportunities within California for CCS retrofit on existing facilities including 25 natural gas combined cycle power plants, 16 hydrogen plants, 15 combined heat and power

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[11] National Energy Technology Laboratory, Permanence and Safety of CCS, Accessed June 29, 2021. https://netl.doe.gov/coal/carbon-storage/faqs/permanence-safety

[12] National Energy Technology Laboratory, "Safe Geologic Storage of Captured Carbon Dioxide: Two Decades of Doe's Carbon Storage R&D Program in Review", April 13, 2020. https://netl.doe.gov/sites/default/files/Safe%20Geologic%20Storage%20of%20Captured%20Carbon%20Dioxide_April%2015%202020_FINAL.pdf

[13] Global CCS Institute, "Global Status of CCS Report 2020". https://www.globalccsinstitute.com/resources/global-status-report/

[14] Energy Futures Initiative and Stanford University. "An Action Plan for Carbon Capture and Storage in California: Opportunities, Challenges, and Solutions." October 2020. https://sccs.stanford.edu/sites/g/files/sbiybj7741/f/efi-stanford-ca-ccs-full-rev1.vf-10.25.20.pdf [urldefense.us]

plants, nine petroleum refineries, eight cement plants, and three ethanol plants. Costs for retrofit of existing facilities range from as low as \$20/tCO_2 for capture at an ethanol plant to \$131/tCO_2 for combined heat and power plants. The potential emissions reductions from these 76 industrial facilities and power plants were estimated to be 59 MtCO_2.

The Stanford/EFI study focused on facilities located within California. It is worth noting that California imports ethanol and other fuels which could be produced in out-of-state facilities that utilize CCS technologies. There are thus opportunities for facilities outside of our geographic borders to significantly reduce California's overall emissions.

SOURCES OF EMISSIONS, POTENTIAL CAPTURABLE EMISSIONS, COSTS, AND INCENTIVE ELIGIBILITY

Metric	NGCC	Hydrogen	CHP	Refining	Cement	Ethanol
Number of Facilities	25	16	15	9	8	3
Total Emissions, 2018 (MtCO_2e)	21.6	11.2	10.1	6.3	7.8	.43
Assigned Capture Rate	90%	90%	90%	90%	90%	100%
Total Capturable Avoided Emissions (MtCO_2)	27.5	10.1	9.1	5.2	7.0	.43
Weighted Average Capturable Emissions (tCO_2 per facility per year)	1,100,000	630,000	600,000	575,000	880,000	142,000
Estimated Capture Cost Range (\$/tCO_2)	\$62 -\$96	\$58-\$101	\$60-\$131	\$58 -\$73	\$48 - \$75	\$20 - \$23
LCFS Eligibility	No*	Yes**	Yes***	Yes**	No	Yes

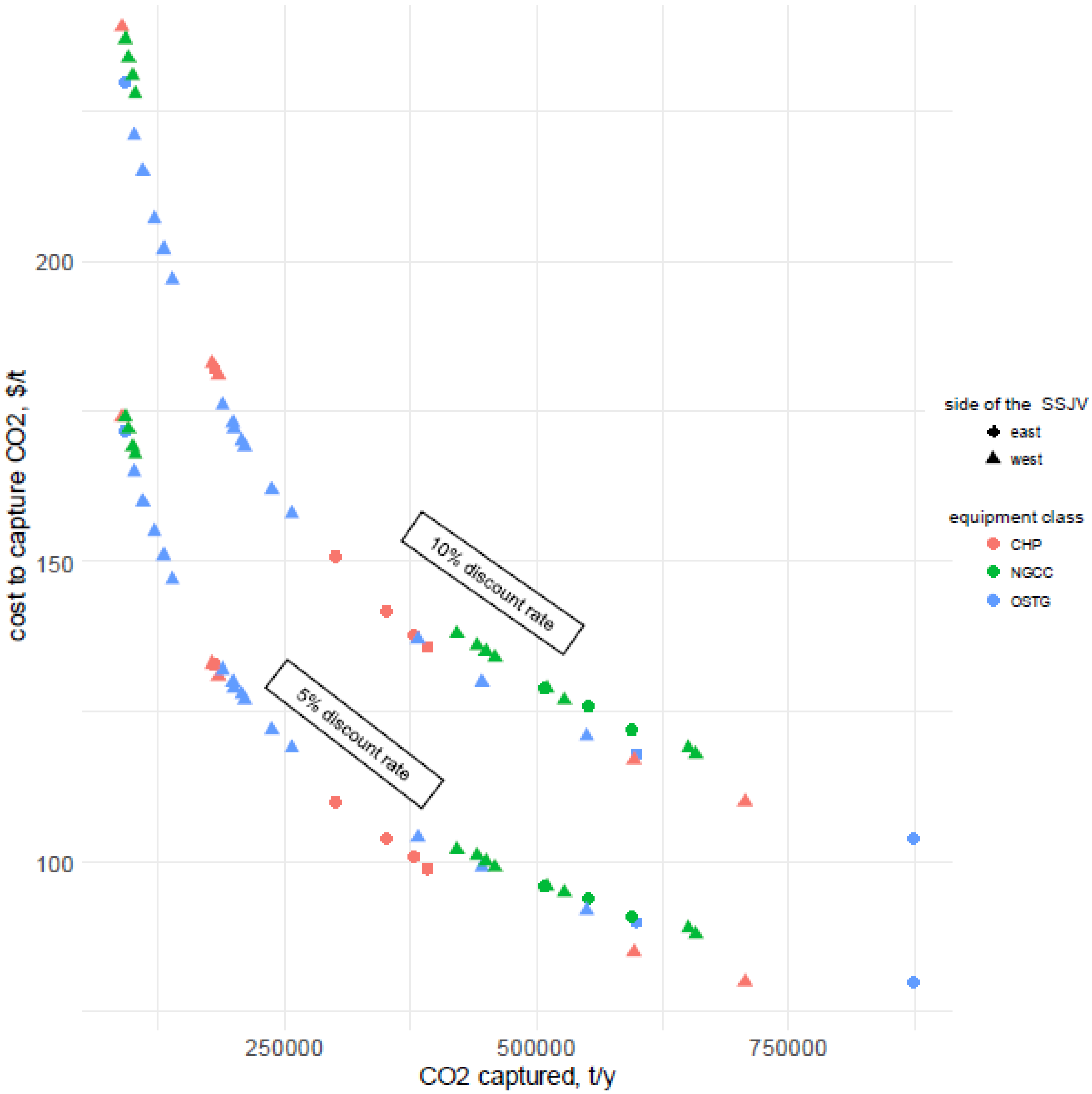
Notes:
* Elk Hills Power is considered 40% LCFS eligible as some of the electricity will be used for oil field operations
**Hydrogen and Refining were considered 80% LCFS eligible as some refined product is exported out of state.
*** CHPs associated with refining operations were considered 60% LCFS eligible due to rationale in ** yet reduced another 20% because some power generated by CHPs is sold to the grid. CHPs associated with upstream oil and gas production activities were considered to be 50% LCFS eligible.

This table provides key details, assumptions, and capture costs for the 76 facilities deemed eligible for CCS retrofit based on this analysis.
Source: Energy Futures Initiative and Stanford University, 2020.

The Electric Power Research Institute (EPRI) has also conducted an analysis of sites as part of the C2SAFE project to develop a facility for permanent storage of CO_2 in a geologic formation in the southern San Joaquin Valley (SSJV) in California.[15] The figure below displays costs per tonne of CO_2 captured assuming a 50% capacity factor, 90% capture of the CO_2, and a 30-year project lifetime for a variety of emitters. The data demonstrates that, as a project scales up the amount of CO_2 captured, the relative costs come down. The EPRI study focused on emitters of over 200,000 tonnes/year of CO_2 and their cost estimates support their focus on larger projects. These location specific costs are in line with those estimated by the Stanford/EFI study. It is

[15] California CO_2 Storage Assurance Facility Enterprise (C2SAFE) Task 2: CO_2 Source Characterization and Capture Techno-Economics
International Energy Agency, "Net Zero by 2050", IEA, Paris, 2021.

reasonable to assume that costs will reduce as more CCS projects are deployed and the available technologies develop and expand.



Plot of the costs reported in Tables 3-9 and 3-10 for the emitters in the SSJV, identified by equipment type (color), side of the SSJV (shape), and discount rate.

CCS and CDR can materially help maintain or even grow a healthy workforce while California achieves deep decarbonization

According to a recent International Energy Agency (IEA) report, energy transitions bring substantial new opportunities for employment, but these opportunities are often in different locations, skill sets and sectors than the jobs in the current shape and form of the energy sector. Structural changes can thus have lasting social and economic impacts on individuals and communities, and the people involved have to be treated as active participants in the transition.

First-of-a-kind analyses outline the capability for CCS and CDR technologies to contribute towards the direct maintenance of continuity of family-sustainable, fully-benefitted employment.[16] In California, these are known as "high road" jobs, and can be readily identified as including:

1. Retrofits to existing oil and gas facilities;
2. Retrofits to manufacturing and other industrial facilities;
3. Expansion to existing plants and creation/construction of additional CCS hubs;
4. Development of biofuels and synthetic fuels facilities;
5. Delivery systems for associated infrastructure (pipe laying, welding, product/lab testing, etc.); and
6. Other potential applications within production plants.

The challenge will be once the retrofits and expansions are complete, to ensure blue-collar sector jobs beyond this limited scope, as most of those will be in communities that are already susceptible to sustaining a disproportionate occurrence of job losses.

As advances in renewable energy sectors are achieved, the compensation associated with them should be reflective of their carbon merits. The opportunities that expediting and employing CCS and CDR technologies offers will place us more firmly on a pathway to better-paying jobs that are more equitable than those that will be lost as we transition further into a clean energy economy, particularly in sectors that will incur large transitional job losses, such as the fossil fuel industry. As it happens, there is strong overlap between the skills of today's workforce and those needed to make CCS and CDR real contributors to California's climate goals: pipe fitters, welders, engineers, geologists, and much more. Policy drivers for deploying CCS and CDR technologies in California will translate to tangible job growth and increased employment opportunities.

Seeking to secure a relatively seamless transition in the view of the average working family entails having a secure job supply to meet the demand. Ready and reliable employment opportunities coupled with the infrastructure investment to get California to carbon neutrality is a crucial combination for success, and CCS and CDR technology deployment are key for achieving this.

Conclusion

We thank CARB once again for the opportunity to comment and engage in this Scoping Plan Update, and urge consideration of the full value of CCS and CDR technologies for California: carbon, air quality, and workforce transition. We stand ready to provide further information on these technologies for the purpose of the Scoping Plan Update and beyond.

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[16] John Larsen et al., "The Economic Benefits of Industrial Carbon Capture: Investment and Employment Opportunities for Eastern and Western States", Rhodium Group, January 28, 2021. https://rhg.com/wp-content/uploads/2021/01/The-Economic-Benefits-of-Carbon-Capture-State-Investment-and-Employment-Estimates_Phase-II.pdf#page=15

Respectfully submitted,

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