THE INTERNATIONAL COUNCIL
ON CLEAN TRANSPORTATION

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November 1, 2013

RE: California Air Resources Board's *Climate Change Scoping Plan First Update*

The International Council on Clean Transportation (ICCT) welcomes the opportunity to provide comments on the California Air Resources Board's *Climate Change Scoping Plan First Update: Discussion Draft for Public Review and Comment.* The ICCT is an independent nonprofit organization founded to provide first-rate, unbiased research and technical analysis. Our mission is to improve the environmental performance and energy efficiency of road, marine, and air transportation, as well as their fuels, in order to benefit public health and mitigate climate change.

The ICCT has long supported, and welcomes the opportunity to provide comments on, California's efforts to mitigate global climate change. We commend the Air Resources Board for its continuing efforts to promote a cleaner, lower-carbon economy and especially for its leadership in the transportation sector. We hope these comments can help in the dialogue to continue to develop a comprehensive long-term strategy to stabilize the effects from human-caused climate change.

We would be glad to clarify or elaborate on any points made in the attached comments. If there are any questions, Air Resources Board staff can feel free to contact our US program co-Lead, Dr. Nicholas Lutsey (*nic@theicct.org*).

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Comments on *California Air Resources Board's Climate Change Scoping Plan First Update: Discussion Draft for Public Review and Comment*

Submitted by

International Council on Clean Transportation

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I. Introduction

The International Council on Clean Transportation (ICCT) has long supported the State of California's visionary and science-based approach to achieve its air quality and climate change mitigation goals. Primarily led by the California Air Resources Board (ARB), the State's overall policymaking efforts have been impressive from a global perspective. ARB's policymaking has been comprehensive across all major carbon-emitting sectors, systematic in strategically prioritizing actions, and thorough in its enforcement of its policies.

But perhaps what stands out most in California's policymaking efforts is how the ARB for been such a consistent thought leader in developing the full portfolio of climate change mitigation strategies that eventually are adopted elsewhere. As a primary role of the ICCT is to help disseminate best practices around the globe, naturally the California climate mitigation policy portfolio has many of the transportation actions that the ICCT points to in advising international policymakers in their energy and carbon policy decisions. It is with this general commendation of the ARB's climate mitigation policy leadership, that we make the following comments specifically about the discussion draft of the 2013 Climate Change Scoping Plan First Update ("Plan" hereafter).

Our comments relate almost entirely to the transportation elements of the Plan, touching on major elements related to efficiency across the transportation modes, alternative fuels, the importance of short-lived climate forcing pollutants (particularly black carbon), and several notes on national and international collaboration. Overall, the ICCT finds that the Plan offers a clear-headed and rational slate of actions that appropriately build from the foundational vehicle and fuel policies that are already demonstrating clear success in California. A number of more specific comments and suggestions for consideration are described below.

II. Efficiency

This section provides ICCT's comments on the need to increase efficiency across the various transportation modes within California's climate action plan. The discussion includes subsections on light duty vehicle efficiency, heavy-duty vehicle efficiency, ocean-going ships, and aviation.

Light-duty vehicle efficiency

The ARB's leadership in accelerating developments in light-duty vehicle efficiency has been very strong. The original California greenhouse gas emission regulations for

2009-2016 laid the groundwork for federal 2012-2016 federal US Environmental Protection Agency (US EPA) and the National Highway Traffic Safety Administration (NHTSA) standards. More recently ARB worked with US EPA and NHTSA to develop the California and federal 2017-2025 GHG standards that reduce new light-duty vehicle greenhouse gas emissions by approximately 4.5% per year. This set a technically vetted standard that promotes advanced technology in a highly cost-effective manner, with benefits that are at least three times the cost and a three-year payback period for consumers. This California leadership has helped put US vehicle efficiency on a trajectory that is more consistent with other leading regions around the world like Europe and Japan (ICCT, 2012).

Setting long-term percent-per-year targets is important and worthwhile to clearly illustrate the various regulatory programs' challenge in helping to achieve overall climate goals. Such annual percentage goals are also important as early non-regulatory signals to motivate and provoke discussions with manufacturers and the broader supplier base that are linked to long-term goals that go well beyond near-term compliance. The ARB's long-term vision of 5% per year for new vehicle GHG emission reduction is supported by wide-ranging authoritative studies from government agencies and leading researchers. For example, major analyses by government regulators, including the ARB, US EPA, and NHTSA, that draw from leading independent and industry sources support substantially lowering the carbon dioxide equivalent (CO_2e) emission levels further beyond 2025. The three agencies together demonstrated four cost-effective technology scenarios that would achieve "62 mpg" or 143 g CO_2/mile (compared to "54 mpg" or 163 g CO_2/mile in the final rulemaking[1]) (US EPA, NHTSA, CARB, 2010). These scenarios demonstrated 3-4 year payback periods and benefits that are three times the incremental vehicle technology costs.

Since the 2012 rulemaking for 2025 standards, new supporting information shows that much more technology is still on the table for increasingly stringent standards from 2025 on. Among the technologies that have far more potential than implied by the US EPA, NHTSA, and ARB 2017-2025 regulatory analyses are lightweighting, improved engines, and hybrids.

The federal agencies suggested that lightweighting technology might achieve just 8% new fleet mass reduction in the model year 2025 timeframe (US EPA, 2012). Recent work by EDAG (Singh, 2012), FEV (2012), the Aluminum Association (EDAG, 2013; Bull and Richman, 2013), and WorldAutoSteel (EDAG, 2011) all suggest that 15-30% mass reduction can be done at substantially lower incremental cost than the agencies estimated, with multiple material and design solutions, and without compromise in safety or crashworthiness. The California-funded Lotus (2012) study goes further, indicating that more advanced mass reduction technology can achieve at least a 30% mass reduction on a crossover utility vehicle, at comparable net vehicle costs while

[1] Quotes used because the fuel economy is based on direct test cycle combined fuel economy and assumes that air conditioning credits are not utilized

meeting all crashworthiness requirements.

The most advanced internal combustion engine modeled by the agencies in support of the 2017-2025 rule was a boosted-exhaust gas recirculation (EGR) engine, or an engine that uses the turbocharger to boost EGR in addition to intake air. EPA developed an Energy Audit model that appropriated the loads and losses from Ricardo's modeling of various engine technologies into various categories. The 2013 National Academy of Sciences' *Report on Transitions to Alternative Vehicles and Fuels* used the EPA Energy Audit model to calculate an average indicated engine efficiency of about 36.4% for the 2008 baseline vehicle and 38.7% for the boosted-EGR engine. However, only 6% of the 2025 fleet was projected to need this boosted-EGR to comply with the 2025 standards, with the rest of the fleet using downsized-turbocharged engines with less than 38% indicated efficiency. Much more importantly, engine development has already moved well beyond what was known during development of the 2025 rule. For example, Peugeot has announced production plans for a dedicated-EGR engine for the 2018 model year. This engine takes the exhaust of one of the four cylinders and feeds it back into the engine intake, which means that the engine always runs with 25% EGR. Further, because the exhaust from this cylinder does not go out the exhaust, it can be run rich to create hydrogen. The hydrogen assists with the combustion process, improving combustion stability and allowing higher compression ratios. According to Terry Alger of Southwest Research Institute, which is heading a consortium working on engines with high rates of EGR, this dedicated-EGR should have indicated efficiency of at least 42% (Greencarcongress, 2013). This is about an 8% increase over the boosted-EGR engine and about 10% over the high volume engine modeled for 2025 by the agencies. Additional efficiency improvements beyond this are extremely likely by 2035. Engine efficiency technologies like these will continue to emerge in the 2020-2030 timeframe to enable 5%/year fuel consumption reductions.

In addition, the agencies projected only 5% of the new 2025 sales fleet would be parallel or powersplit hybrids (US EPA, 2012). Less than half of the fleet was projected to even have a stop-start system in 2025. Hybrids are now, in 2013, breaking beyond the early adopters with 7% of the California new sales market and 15% of Toyota's US sales due to more mature technology offerings across the major companies and across the major vehicle classes. In addition, further hybrid cost reductions are expected with the development of high-power lithium-ion batteries around 2015. Current batteries for hybrids are oversized, in order to provide sufficient power for acceleration and regenerative braking without deterioration. High-power lithium-ion batteries are being developed that will be able to provide the needed power with a battery pack just one-third to one-half the size of current hybrid battery packs, for significant cost savings.

These are just a sampling of the larger efficiency benefits that will be available in the future. Of course many technical questions related to additional technology developments will need further examination in the US mid-term review for 2017-2025 standards.

Figure 1 shows, in fuel consumption terms, how the California 5% per year trend for new vehicle standards post-2025 compares with the recent seminal long-term study of the National Research Council (NRC, 2013). The figure indicates several points quite clearly about how the targets relate to given technologies in the new light-duty vehicle fleet. First, the 5%/year targets are technically achievable, based on best available combustion technologies like advanced gasoline powertrains and load reduction technology (e.g., lightweighting, aerodynamics, tires) through about 2030. Second, the 5%/year targets are primarily achievable with internal combustion technology with hybrid technology through 2035-2040. Third, only from 2040-2050 are fuel cell electric and hydrogen fuel cells necessary to achieve the compounding 5%/year targets. Relatedly, the federal agencies have very low estimations of the potential of electric drive vehicles in the 2025 timeframe. For example, electric-drive vehicles in 2013 make up about 0.6% of new sales (Hybridcars, 2013), whereas the federal agencies projected only 2% of 2025 sales would be electric drive. So this underscores the importance of the Zero Emission Vehicle program, and its supporting policies, to accelerate the deployment of these electric-drive technologies to achieve the long-term GHG emission targets.

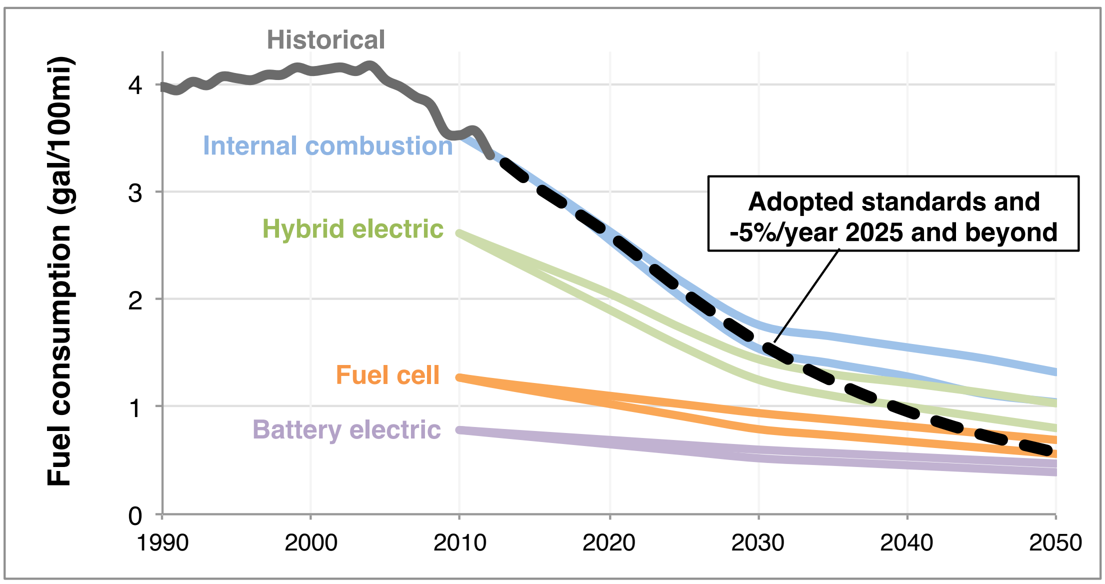

Figure 1. California target for 5% per year light-duty vehicle regulatory stringency, compared with National Research Council (2013) long-term efficiency technology assessment

The ICCT commends the ARB on the comprehensiveness of its long-term plans to promote electric drive vehicle technologies. We note two very important recent studies – Greene et al (2013) and NRC (2013) – point to the many uncertainties in mass commercialization of electric-drive vehicle technology over the long-term. These studies show the importance of the roles of vehicle and fuel policy, consumer uptake by early adopters and mainstream customers, ways to help address consumer risk aversion, and necessary infrastructure investments in transitioning to an electric drive fleet. And the ARB scoping plan has elements that hit directly at each of these components, so we emphasize the importance of ARB finding a way to implement these ideas. California's global leadership in electric-drive depends not just on its pioneering vehicle and fuel policy, but also on delivering the blueprint and funding support for hydrogen refueling and fast-charging networks to match the vehicle roll-out.

One area in the Plan that might be reexamined is the targets for the sales share of electric-drive vehicles. We note that the Plan's indicated target for the Zero Emission Vehicle (ZEV) program (i.e., one percentage point per year increase after 2025) would be far lower than the amount of electric-drive vehicles that would likely be needed to achieve a climate stabilization scenario (see, e.g., Williams et al 2012). It is highly likely that the majority of new vehicle sales will need to be hydrogen fuel cell or plug-in electric by 2040 to have any chance at a vehicle fleet that is consistent with climate stabilization, considering the delay of fleet turnover effects, and especially considering how it is more difficult to fully convert the other transportation modes to electric drive. Noting that the NRC (2013) work referenced above indicates that electric-drive technology would not be required for 5%/year annual stringency requirements even through 2035, policies like ZEV will be required to accelerate electric drive to achieve climate stabilization scenarios.

A light-duty vehicle efficiency technology that deserves greater attention in California's climate action plan is reducing the rolling resistance of replacement tires in the light-duty vehicle fleet. Original equipment tires are substantially lower rolling resistance – approximately 20% lower – than replacement tires (TRB, 2006). At a minimum, consumers need information to better understand their tire purchasing options and how it will impact their vehicle efficiency. Further, regulatory policy that ensures replacement tires have the same efficiency as the original tires that automakers equip new vehicles with could ensure that the "other ~90%" of US tires on the road see the same efficiency as US EPA new light-duty vehicle fuel economy labels suggest that they should get. California's tractor-trailer GHG rule is a step in the right direction to ensure the entire fleet increasingly gets high-efficiency tires. The California Energy Commission has apparently aborted its efforts toward a replacement tire efficiency policy. Perhaps this effort could be revived with a regulation that builds from the known tire technology developments that enter the new vehicle fleet as automakers comply with new standards through model year 2025. Also, perhaps such a regulation could be aligned with NHTSA's efforts toward a federal voluntary tire labelling regulation.

Over the long-term, autonomous or "driverless" vehicles warrant further investigation. The year 2050 is a long ways away, and autonomous vehicle technologies offer enormous potential for an optimized transportation system to help improve traffic, congestion, quality of life, and safety. Along with Google's technology developments in this area, recent announcements by Nissan, Daimler, and other auto companies suggest that commercial deployment could occur in significant numbers in the 2025 timeframe. Certainly the non-climate considerations (driver comfort, safety, policy) are driving this technology's deployment, but the potential climate impacts in the long term are also enormous. Over the very long-term, the potential for an entire fleet of autonomous vehicles to far more efficiently move as a network (i.e., improve on-road efficiency, minimize acceleration, deceleration, and idling), almost entirely avoid crashes, dramatically reduce the vehicles weight, and thus enable mainstream electric drive technology, is profound and should be explored. Even if this seems implausibly futuristic, the truly transformative nature of such a technology should be considered in a 2030-2050 timeframe. We recommend greater ARB research into the prospects for this technology, its network benefits, and synergies with lighter mass-market electric drive vehicles.

Heavy-duty vehicle efficiency

The ARB Plan makes a number of important statements about reducing the GHG emissions from the heavy-duty vehicle fleet and freight transport more broadly. The Plan rightly puts focus on achieving reductions in new truck technology as well as the existing fleet of trucks. This is especially important for this sector where trucks, tractors, and trailers remain in the fleet for decades. For new trucks, the Plan provides a strong vision for 5% per year GHG emission reductions, and this target is appropriate and consistent for purposes of setting a plan for achieving climate stabilization. Such a target will be necessary (just as above for light-duty) for this mode to proportionally help in bringing the dramatic carbon reductions that will be necessary for climate stabilization.

The primary reason that so much GHG emission reduction is possible in the heavy-duty vehicle sector is that the first phase of standards (i.e., for 2014-2018) was an initial framework for standards that left many available and emerging technologies on the table. Areas for increased efficiency in heavy-duty tractor-trailers that can be achieved in the 2015 to 2025 timeframe as compared to a model year 2010 baseline are shown in Table 1. There are entire major categories of technologies that are not being promoted in the Phase 1 rulemaking. In tractor trailers, advanced automated manual transmissions and dual-clutch transmissions with integrated engine control approaches can bring an approximate 10% efficiency gain; however, transmissions are not included in the standard certification protocol in Phase 1. Trailer aerodynamics and tires are good for another approximate 10%+ in fuel consumption and CO_2 reduction (Sharpe et al, 2013). These trailer-associated gains could be included in the second phase of the federal regulations to ensure that the technology packages from the California GHG fleet regulation are embraced by the full US fleet.

Table 1. Class 7-8 tractor-trailer technologies for CO_2 emission reduction

Area	Technology	Potential CO_2 emission reduction
Engine	Engine friction and parasitic load reduction (piston; water, fuel, oil pumps)	0.5 – 1.5%
	Advanced controls, combustion, fuel injection improvements (fuel rail, injector, cylinder head, EGR improvements)	0.5 – 2.5%
	Aftertreatment improvement	0.5 – 1.5%
	Turborcharging efficiency and air handling improvements	1.0 – 1.8%
	Mechanical turbocompounding with clutch	2.5 – 5.0%
	Electric turbocompounding	2.5 – 6.0%
	Waste heat recovery with organic Rankine cycle	4 – 8%
Transmission	Downspeeding with engine downsizing	3 – 6%
	Appropriate gear and gear ratio specification	1 – 3%
	Friction reduction and improved transmission efficiency	1 – 1.5%
	Direct drive	1.5 – 2%
	Single drive axle	1%
	Automated manual transmission	4 – 8%
	Automatic transmission	0 – 5%
	Dual clutch transmission	2 – 5%
	Hybrid architecture (regenerative braking coasting and motoring)	4 – 10%
Tractor	Aerodynamics - Day cab roof deflector	3 – 5%
	Aerodynamics - Sleeper roof fairing	3 – 5%
	Aerodynamics - Chassis skirt	3 – 4%
	Aerodynamics - Cab extender	2 – 3%
	Low rolling resistance steer/drive tires	1 – 3%
	Weight reduction – aluminum, single wide	0 – 1%
	Auxiliary power unit	5 – 6%
	Road load management (GPS, predictive cruise, driver feedback)	0 – 5%
Trailer	Aerodynamics - Partial skirts (4 – 6 m)	3 – 4%
	Aerodynamics - Full skirts (7 – 9 m)	4 – 6%
	Aerodynamics - Partial gap reducer (cuts gap ~ in half)	1 – 2%
	Aerodynamics - Full gap reducer (fully closes gap)	2 – 3%
	Aerodynamics - Boat tails	4 – 6%
	Low-rolling resistance tires	1 – 2%
	Improved wide-base single tires + aluminum wheels	4 – 6%
	Partial aerodynamic package	4 – 8%
	Full aerodynamic package	7 – 11%

Based on Sharpe et al, 2013

In addition to trailers, tires, and transmissions, there are a number of diesel engine approaches that can advance the powertrain much further than today's technology. For example, waste heat recovery via an organic Rankine cycle, turbocompounding, and other advanced powertrain technologies that enable downspeeding and downsizing of the engine, are all being actively explored. A recent Cummins paper suggests that the modern diesel engine can improve by over 20% from a 2010 baseline, with downspeeding, aftertreatment, lubricant viscosity, turbocharging efficiency, higher efficiency oil and water pumps, reduced EGR, optimized air treatment, friction reduction, reduced heat transfer, increased compression ratio, reduced engine backpressure, Waste heat recovery, and active powertrain optimization (Stanton, 2013). The paper indicates that the same 20%+ efficiency gain is achievable in line-haul applications and for vocational applications. This 20% potential compares with only an approximate 6% diesel CO_2 emission benefit that is required from the Phase 1 US 2014-2018 standards that a number of engine manufacturers are already achieving.

Indications of the feasibility of achieving such substantial long-term CO_2 reductions in heavy-duty engines, trucks, tractors, and trailers are seen in analyses and industry reports on their technology development efforts. Earlier work by the TIAX (2009) and National Research Council (NRC, 2010) suggested that 30-45% fuel use and CO_2 reduction is possible across heavy-duty truck types. This compares to the approximate 6-23% reduction in the Phase 1 rulemaking (ICCT, 2011). In addition, a recent update from ACEEE (2013) makes the case that the new Phase 2 standards could reasonably achieve about a 26% fuel consumption reduction (averaged across the truck types), beyond the already adopted Phase 1 standards. The latest NRC (2013) heavy-duty vehicle committee's meetings have continued to provide a strong sense that more advanced engine, transmission, aerodynamic, tire, trailer, and hybrid technologies are emerging that could go further than the previous studies indicated.

Further, the series of US Department of Energy SuperTruck projects have shown that even far more advanced heavy-duty vehicle technologies are available in the mid-term. These SuperTruck technologies, in turn, give further credence to the ARB's 5% per year targets CO_2 reduction targets for heavy-duty vehicles. The SuperTruck projects involve $115 million in public US funding to help advance tractor-trailer efficiency technology. The program's 2011-2013 goals were for a 50% increase in ton-miles per gallon efficiency and to achieve 50% brake thermal efficiency (BTE) versus approximately 42% for a 2010 baseline. The follow-on 2014-2015 goals are to achieve a 68% increase in ton-mile-per-gallon efficiency and 55% brake thermal efficiency. The various programs are led by Cummins, Detroit Diesel, Volvo, and Navistar, and these manufacturers represent over three-quarters of the Class 8 US tractor market. The projects have already shown immense progress in demonstrating these technology goals are achievable for tractor-trailers. For example, the Cummins program has reached 51% engine BTE, and 61% freight efficiency improvement (Koeberlein, 2013). This translates to about 38% reduction in fuel consumption from baseline 2010 technology. These SuperTruck projects provide go beyond the basic research to show physical proofs-of-concept that these technologies could become widespread from 2020-2030; as a result, Phase 2 of the US standards should seek to accelerate the adoption of these technologies.

As the use of technologies promoted by California's tractor-trailer fleet GHG rule and federal efficiency policy becomes more widespread, the nationwide acceptance and demand for the various efficiency technologies can continue to increase. A recent study, in collaboration with the ICCT, interviewed over 1800 owner-operators and fleets that represent over 50,000 tractors and 100,000 trailers to better understand their efficiency adoption practices (see Roeth et al, 2013). The study shows that eagerness to purchase various technologies (e.g., aerodynamics, and lower rolling resistance tires), but that there are noted barriers. The study points out barriers of limited availability of technology, lack of credible information about the benefits of new technologies, lack of access to capital for the incremental technology costs, and uncertainty about the length of time required for fuel savings to pay back the investment in equipment. ARB has a clear role in helping surmount these barriers, with the adopting of long-term greenhouse gas regulations, publicizing data about the efficiency of new truck technologies from their vehicle emission testing programs, and providing outreach and awareness campaigns to get more information to more drivers and fleets. It is notable that the California GHG tractor rule continues to have substantial and positive spillover effects in helping to bridge the information gap on the benefits of new emerging efficiency technologies and in accelerating the technology deployment beyond California's borders.

Aside from the tractor-trailer segment, the heavy-duty vehicle area where the technology potential for dramatic GHG mitigation may be greatest is the lightest heavy-duty vehicles. The commercial pickup and van segment (generally Class 2b and 3 trucks between 8,500 and 14,000 lbs gross vehicle weight rating) are close cousins to the pickup and van models that are classified in the light-duty vehicle regulation.

The Phase 1 heavy-duty rulemaking requires that these commercial pickups and vans reduce their fuel consumption by approximately 10% in the 2018 timeframe (from a 2008-2010 baseline). The subsequent 2012 analysis for the light-duty vehicle 2017-2025 rulemaking utilized a suite of more detailed peer-reviewed technical analyses (e.g., Ricardo, 2011; FEV, 2013) and technical exchanges with the same major automakers to develop far more stringent longer-term standards. The footprint-indexed light-duty vehicle regulation requires about a 23% fuel consumption reduction for full-size pickups and vans in the 2018 timeframe, and a 40% fuel consumption reduction in the 2025 timeframe (again, from a 2008 baseline). As a result, the light-duty standards currently push far more advanced technologies, at far greater numbers, into the fleet than the heavy-duty commercial pickups and vans.

The technologies identified to achieve the required 2025 efficiency improvement in the light duty vehicles are shown in Table 2. Most of the same efficiency technologies are directly applicable to the light- and heavy-duty versions of pickups and vans. There is a long history of incremental efficiency technologies working their way from automobiles, to sport utility vehicles, to larger light trucks, to medium duty vehicles. Efficiency technologies for engines (e.g., dual overhead cams, variable valve timing), transmissions (e.g., torque convertor lockup, 6-speed transmissions), have migrated to larger vehicles. Similarly, the next slate of efficiency technologies, like downsized turbocharged engines, direct injection, lightweighting, and dual-clutch eight-speed transmissions appear to be next in line to diffuse upward into larger vehicle classes.

Table 2. Technologies and percent fuel consumption improvement for commercial heavy-duty pickups and vans

Area	Technology	Percent fuel consumption and CO_2 reduction	Applicability for heavy-duty vans, pickups	
			Gasoline	Diesel
Engine	Engine friction reduction (2.5%)	2.4%	✓	✓
	Engine friction reduction (3.5%)	4.2%	✓	✓
	Cylinder deactivation	5.7%	✓	✓
	Discrete cam phasing (DCP)	4.9%	✓	✓
	Discrete variable valve lift (DVVL)	4.9%	✓	✓
	sGDI (18-bar, 33% downsize)	13.6%	✓	
	sGDI+DCP+DVVL (18-bar, 33% turbo downsize)	16.8%	✓	
	cEGR sGDI+DCP+DVVL (27-bar, 56% turbo downsize)	23.5%	✓	
Transmission	Torque convertor lock-up	0.5%	✓	✓
	Aggressive shift logic	2.4%	✓	✓
	High efficiency gearbox	4.3%	✓	✓
	Optimized shifting	6.2%	✓	✓
	6-speed automatic	2.1%	✓	✓
	8-speed automatic	7.8%	✓	✓
	Wet dual clutch 8-speed	11.9%	✓	✓
	Dry dual clutch 8-speed	12.6%	✓	✓
	Continuously variable	-	✓	✓
Vehicle load and accessory	Low drag brakes	0.8%	✓	✓
	Secondary axle disconnect	1.6%	✓	✓
	Electric power steering	0.8%	✓	✓
	Improved accessories	3.5%	✓	✓
	Mass reduction (10%)	5.1%	✓	✓
	Mass reduction (20%)	10.4%	✓	✓
	Tire low rolling resistance (10%)	1.9%	✓	✓
	Tire low rolling resistance (20%)	3.9%	✓	✓
	Aerodynamics (10%)	2.3%	✓	✓
	Aerodynamics (20%)	4.7%	✓	✓
Hybrid	12V stop-start	6.5%	✓	✓
	High-voltage belt-alternator	8.0%	✓	✓
	Parallel hybrid (23-40 kW electric motor size)	31.9%	✓	✓

CO_2 = carbon dioxide: cEGR = cooled exhaust gas recirculation ; sGDI = stoichiometric gasoline direct injection
Based on EPA (2012) and Ricardo, 2011); percents on not additive

These are just a sampling of the larger efficiency benefits that will be available in the future for heavy-duty vehicles. Of course many technical questions related to technology developments will need further examination in the on-going development of Phase 2 heavy-duty standards for the US and for California.

The ARB target of an annual 5%-per-year GHG emission reduction through 2025 or 2030 also points to a critical more general question about regulatory lead-time. We note that there can be significant differences light- and heavy-duty vehicle industry cycles for research and development, engineering, pilot testing, and deployment for new technologies. Whereas a competitive car industry and its associated consumer demands have pushed a relatively rapid 4-6 year vehicle redesign cycle into common practice, heavy-duty vehicles tend to have longer 6-10 year cycles for rolling out substantially new engine, transmission, etc technologies. This has a direct ramification for establishing a long regulatory timeline for the Phase 2 heavy-duty standards that ARB and federal agencies will develop. The 13-year regulatory lead-time for light duty vehicle standards (i.e., 2012 adoption of 2025 standards) was well justified as it is appropriate to reduce technology investment risk and sustain more dramatic capital investments by industry (Lutsey, 2013).

The rationale for a long regulatory lead-time – to beyond model year 2025 – is even clearer for heavy-duty vehicles, if substantial technology penetration for greater energy and GHG emission benefits is a major goal of the Phase 2 program. This is especially fitting for the very difficult task of launching advanced efficiency technologies for deeper long-term GHG emission cuts that the ARB is pursuing beyond 2025. To promote long-term heavy-duty vehicle efficiency technology, standards through model year 2030, adopted in the 2015 timeframe, are recommended for ARB (and its aligned federal agencies). Such a regulatory lead-time is sufficiently long to allow for greater investment security in new technologies and time to sustained long-term investments in engine and vehicle efficiency technologies with increasing long-term technology sales.

Going beyond truck efficiency, the ARB also has a real opportunity to expand its leadership in electric-drive technologies into heavy-duty vehicles and the freight sector more broadly. Results from several recent projects indicate that to reach 2050 climate stabilization goals, electric-drive technologies will be needed not just for automobiles but also for heavy-duty vehicles. Electric-drive heavy-duty vehicles (including battery electric and hydrogen fuel cells), would have to start entering the market around 2020 such that by 2035-2045, the most new sales of HDVs are electric-drive and predominantly fueled by ultra-low-carbon energy sources. Along with ARB’s 2012 “Vision” analysis (ARB, 2012), several other works also provide additional analysis and important considerations for ARB in this area. For example, the Sharpe (2013) assessment makes it clear that either plug-in electric and fuel cells-based heavy-duty vehicle scenarios for climate stabilization could have benefits that are more than double the incremental technology costs. Also the recent CalHEAT work lays forth several considerations related to an electrified corridor for urban freight movement (Silver and Brotherton, 2013).

We also would point the ARB staff to recent EU-based study demonstrates the potential for zero emission (electric and fuel cell) freight technology to become cost-effective by 2030 or earlier, and government leadership to build the necessary infrastructure (charging or hydrogen) could significantly accelerate that trend (Boer et al, 2013). Similar to the Boer et al (2013) study, we recommend that the State consider electric drive technologies’ full total cost of ownership to help understand the relative benefits of promoting, for example battery electric for urban truck applications and hydrogen fuel cell tractor-trailer over the much longer term.

The ICCT strongly supports ARB's efforts that help to make the South Coast Air Basin a zero emission freight corridor, with state-of-the-art electric technology for trucks, rail, and port equipment in the 2015-2025 timeframe. This could serve as a showcase global zero-emission freight corridor, in a similar way to the ARB vision, planning, and policy for a zero-emission light-duty vehicle sector through accelerated electric-drive vehicle deployment. Figure 2 estimates the in-use fleet composition needed to reduce GHGs by 80% below 1990 levels by 2050 (Sharpe, 2013). If ARB would lead in implementing a vision for long-term ultra-low carbon heavy-duty vehicles, perhaps starting in the South Coast, it would provide a template to follow elsewhere. Expansion of either the ZEV program (into heavy-duty vehicles) or the tractor-trailer GHG rule (into electric-drive technologies for larger fleet) could be considered by ARB, along with aligned fiscal incentives and public infrastructure.

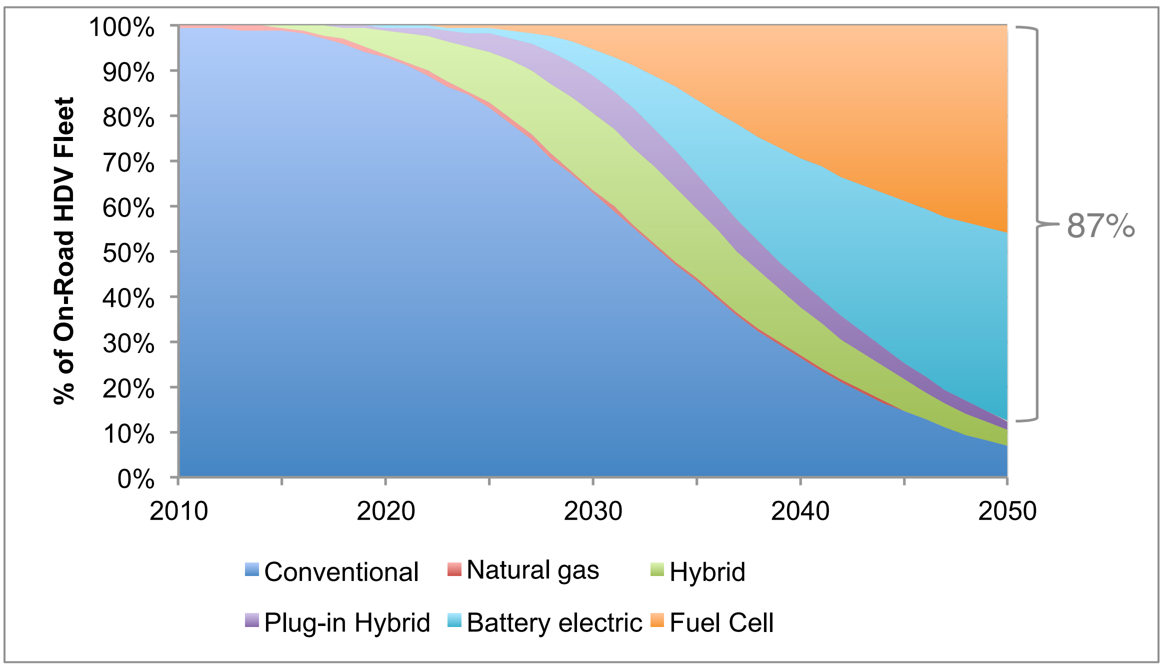

Figure 2. Heavy-duty vehicle technology penetration scenario for climate stabilization

Ship efficiency

One transport mode where California has shown less leadership in climate change mitigation is shipping. Globally, maritime shipping is responsible for about 1000 million metric tons carbon CO_2e per year. Global shipping emissions are twice the emissions of the entire state of California. However, there is immense potential to mitigate the GHG emission impacts from shipping through the adoption of leading industry technologies and practices (Wang and Lutsey, 2013). California is a great benefactor of shipping trade as a major exporter and importer and would further its climate mitigation efforts if it took a more active role in promoting greater efficiency technology and practices in the ocean-going fleet.

It is notable that the California action plan does not fully account for the contribution of shipping to California's greenhouse gas (GHG) inventory. While this is not unusual – around the world, State or regional emission inventories typically do not account for such emissions – California's strong leadership in climate change mitigation from other sectors and modes suggests a need for a more comprehensive inventory and more proactive support. As discussed at ARB's 2009 Haagen-Smit Symposium, failing to account for shipping emissions in State, Regional, and national GHG inventories leads to a "missing inventory" that, in turn, contributes to the dearth of policy actions to reduce the emissions. In addition to covering all emissions from ships operating within 24 nautical miles of California shores, the ICCT recommends that ARB include estimations of maritime emissions from half of all shipping activity to and from the State in its emissions inventory.

We make this recommendation of developing more complete estimation of the States' shipping activities for more complete and accurate GHG inventory purposes; however, we acknowledge that the State's authority to directly impact those activities through policy comes through federal and international processes. The primary point for any major policy action on emissions from ocean-going vessels is the International Maritime Organization (IMO). California could support the US delegation's efforts to develop a proposal for measures to improve in-use ship efficiency (IMO 2013) by taking a greater role in the IMO deliberations by providing supporting data and analysis. California could consider participating in the IMO proceedings indirectly, through supporting research, or directly by participating in a relevant observer organization. California can also facilitate IMO discussions on control measures for black carbon by funding and submitting additional research to IMO on the measurement and characterization of black carbon emissions from international shipping.

Given the long lifetimes of marine vessels and equipment, measures to mitigate or offset emissions from in-service vessels will be particularly important. California already has two regulations in place that could be adapted for the marine sector – ARB's cap-and-trade program and the Low Carbon Fuel Standard (LCFS). The use of either of these policies would more inclusively cover all petroleum-based fuels and help in the shift toward alternatives to oil over the long-term. If marine fuels were incorporated into the LCFS, care should be taken to consider the impact of various delivery and bunkering practices, as those have been found to significantly impact the lifecycle GHG intensity of alternative marine fuels, notably liquefied natural gas (Lowell et al, 2013).

Ports are also important contributors to GHG emission inventories. California could also, via pacts, memoranda of understanding, and partnerships with its major trading partners (China, Mexico, Canada, South Korea, Japan) create voluntary agreements to create "green trade routes" or "clean shipping corridors." Such port-to-port (or state-to-nation) agreements could demonstrate leadership by example, help to sidestep competitiveness issues for shipping companies, and generate experience and data on the potential to reduce carbon footprint of the supply chain that could be replicated elsewhere. Such green trade route pacts could be structured to promote advanced ship efficiency technologies, efficiency practices (e.g., slow steaming), black carbon emission mitigation technology, and alternative fuels (e.g., liquefied national gas). ARB has played such an important role showing the way in the other transportation areas, it could seek to do the same for the marine sector.

Aviation efficiency

Similar to the maritime sector, characterizing and controlling greenhouse gas emission from the aviation sector has been underdeveloped in California's Plan to mitigate GHG emissions. The aviation sector's emissions are large and increasing, with the International Civil Aviation Organization (ICAO) estimating that global CO_2 emissions from aircraft may quadruple from 2006 levels by 2050 (ICAO, 2013).

The ICCT believes that meaningful action to reduce GHG emissions from aviation begins with the proper apportionment of emissions across regulatory bodies, supplemented by better data. California receives great benefits from air travel, yet currently only intrastate emissions – only about 10% of total aircraft emissions – are included in ARB's inventories. The ICCT recommends that California also include half of the emissions from interstate and international flights to and from the state in its GHG inventory, as estimated by the fuel consumed throughout the entire journey on flights departing its airports. If every regulatory agency like the ARB continues to ignore these aviation emissions (and marine emission, as mentioned above) in their inventories, efforts to mitigate these growing emissions will remain limited.

Progress has been made since ARB's first scoping study to better characterize the fuel efficiency of today's new and in-service aircraft as well as the potential for future improvements. ICAO has concluded that the fuel efficiency of new aircraft in 2030 can be improved by up to 70% compared to 2000 levels given proper investment and deployment of advanced airframe and engine technologies based upon today's architectures (ICAO, 2010). Other work has pointed to a slowdown in efficiency improvements over the next two decades due to a lack of new designs begin brought to market and increases in vehicle capability, including range and speed (Rutherford and Zeinali, 2009).

ICAO is working to finalize the world-first CO_2 (efficiency) standard for new aircraft in 2015 to increase the rate of fuel efficiency improvement for new aircraft. As part of these efforts, in February 2013, ICAO finalized a new CO_2 certification procedure to measure and compare the fuel efficiency of new aircraft (Rutherford, 2013). While important, the CO_2 standard will not affect the in-service fleet, and may be applied as a "new type" only standard which grandfathers in most new aircraft through 2030. This is a major loophole given that a typical commercial aircraft may be operated for 25 to 30 years. Recent research estimates that the overall fuel efficiency of US domestic airlines varied by 26% in 2010, and as high as 85% between certain city pairs (Zeinali et.al.

2013). This large gap demonstrates the need for action by States, regions, and countries to develop supporting policies to reduce emissions from in-service aircraft.

Several policy avenues exist for California to address aviation emissions, although direct regulatory approaches on international emissions will be outside of the State's purview. The most straightforward means would be to cover domestic (intra and interstate) commercial aviation flights within and from California in ARB's cap-and-trade program and/or LCFS. Aviation emissions are dominated by a relatively small number of actors, providing a clear regulatory target with low administration costs. Covering domestic US flights under AB32's cap-and-trade system in particular would be consistent with recent discussions at ICAO's 38th Assembly about the appropriate scope of market-based measures (MBMs) that countries can use to control and/or offset aviation emissions.

Other potential areas of action for ARB could include California playing a more active role in collecting and/or disseminating data on GHG emissions from airlines servicing the state. Now that ICAO has finalized a fuel efficiency certification procedure for aircraft, ARB could also work with California airports to develop local incentives to reduce aircraft CO_2 emissions, for example, CO_2 based landing fees. Finally, ARB could sponsor additional research on aircraft emissions to aid EPA in preparing its anticipated endangerment finding for aviation GHGs.

Carbon footprint reporting

We recommend that California consider implementing a carbon footprint reporting and labeling program that incorporates lifecycle impacts and spans the various transportation modes. This could be utilized to help incentivize actions and practices that are not as clearly promoted by the major within-mode efficiency options, like those listed above. Such a move could help address known market barriers related to incomplete information about the energy impacts of goods and services. One such program has been adopted in France (see Franco, 2013), and a program like this would help inform consumers, retailers, and shippers about comparable transport services based on their environmental performance. The France initiative helps give consumers a chance to make improved science-based decisions that incorporate full fuel lifecycle and supply chain carbon emissions from shipping and all other freight modes.

Data from California's Low Carbon Fuel Standard, its heavy-duty vehicle regulatory work, its port policies, new data on shipping emissions (e.g., Smith et al, 2013; Wang and Lutsey, 2013), and new data on aviation emissions (e.g., Zeinali et.al. 2013) could provide the foundation for such a program. A comprehensive carbon footprint initiative could be geared to help individuals, households, and businesses make more informed decisions about how they travel, the products they purchase, and how those goods are transported. The program could aim to provide simple information to consumers at the point of purchase of a good or travel service about the relative greenhouse gas emission impact compared to other options. Such a program could include improved information on commuting and air travel decisions. Ideally the program would prioritize those reporting and labeling actions with greater carbon impacts earlier.

III. Alternative fuels

The transportation sector is globally, and in nearly every major economy, at least 97% fueled by petroleum fuels. This dominance of gasoline and diesel fuels, a vehicle fleet developed for them, and a highly mature fueling infrastructure makes any shift to alternatives slow and challenging. The California mix of policies, including low carbon fuel standard, vehicle regulations, carbon emission trading scheme, consumer incentives, and infrastructure support is as comprehensive as can be found anywhere to promote oil alternatives.

Fundamentally, the long-term transition to an ultra-low carbon transportation sector requires that we get our transportation system largely off of oil. This includes, especially, slowing the movement from conventional oil to higher carbon crudes, such as oil sands and extra heavy oils. The potential for efficiency improvements in vehicles, ships, and aircraft is vast, largely because internal combustion is inherently inefficient. The potential for advanced biofuels is also very large, but limited globally due to land use, sustainability, and competing agricultural demands (biomass for power sector, food, chemicals, materials). Electric drive allows for the highest possible on-vehicle efficiency and enables the most options for near-zero-carbon upstream power (e.g., solar, wind, geothermal, nuclear, hydroelectric, biomass). Ideally California's, and other governments', suite of fuel policies would reduce the demand for all fuels, help to slow investments in high-carbon crudes, accelerate the deployment of ultra-low carbon sustainable biofuels, and accelerate the shift to near-zero carbon electricity and hydrogen electric drive vehicles. To a large extent, current California policies are leading the way in these areas to steer the transportation sector off oil over time.

Continuation, extension, and expansion of the Low Carbon Fuel Standard framework from 2020 is recommended. The carbon intensity of the energy used in transport will have to be reduced by at least 50% (if dramatically increased efficiency occurs) and more like 70-80% (if only moderately advanced efficiency occurs) for California's transportation sector to achieve 2050 climate stabilization goals. The LCFS carbon intensity reduction of 10% by 2020 is only a first step toward this longer-term goal, so we would recommend that indicative 2030-2050 fuel carbon intensity goals be explicitly specified. Such indicative targets will help to provide much needed additional market confidence for ultra-low carbon fuels investors. In addition, the exemptions of aviation and marine fuels, as noted above, within the LCFS are not consistent with long-term climate stabilization. These sectors can all see substantial GHG emission reductions from the use of low-carbon biofuels, natural gas, electricity, and hydrogen beyond 2020.

Overall the fuel carbon intensity has to mimic climate stabilization goals in the long term – fuels would need to achieve an approximate average 50% reduction in fuel carbon intensity in the 2050 timeframe to help achieve an approximate 80% 2050 transport GHG reduction (factoring in both efficiency gains and transport activity growth). Therefore, California would be clearly justified in increasing the LCFS stringency goals from 10% carbon intensity reduction in 2020, to 20% in 2030, to 40% in 2040, to 50% in 2050 to offer strong targets that would require far more electric-drive technology in the fleet. Also we applaud and support California's efforts to expand its LCFS policy to help de-carbonize fuels in other markets, for example in Oregon, Washington, and British Columbia (PCC, 2013). We strongly recommend that California continue its outreach to advance its low carbon fuel policies to other government agencies, domestically and internationally. to help to exert a stronger influence the global fuel market.

Biofuels

In biofuels, it is widely recognized that the speed of deployment of ultra-low carbon cellulosic biofuels has been lower than hoped (for instance by the RFS2 mandate), but the U.S. cellulosic biofuel industry has made critical advances towards full commercialization over the past year. At the end of 2012, KiOR made history by opening the world's first commercial-scale cellulosic biofuel plant in Mississippi. This facility produces drop-in fuels that can be used as fully-blendable substitutes for diesel and gasoline, and thus circumvent the "blend wall". In August 2013, Ineos Bio began production at the world's second commercial-scale plant producing cellulosic ethanol from municipal solid waste, a feedstock that is associated with a very favorable greenhouse gas intensity as it avoids landfill emissions. In Europe, Beta Renewables in Italy has opened the world's first commercial plant converting agricultural residues to ethanol. Other cellulosic biofuel companies are expecting to start production in the U.S. in early 2014, as can be seen in Table 3.

Table 3. US commercial-scale cellulosic biofuel plants in-production or expected to begin production in 2014

Company	Technology	Location	Capacity (million gallons/year)	Date of first production
KiOR	Drop-in cellulosic gasoline and diesel from woody biomass	Columbus, Mississippi	13	December, 2012
Ineos Bio	Cellulosic ethanol from municipal solid waste	Vero Beach, Florida	8	August, 2013
Abengoa	Cellulosic ethanol	Hugoton, Kansas	24	Early 2014
Fiberight	Cellulosic ethanol	Blairstown, Iowa	6	Early 2014

While these companies have proven the technology of cellulosic biofuels and are demonstrating commercial viability, the cellulosic biofuel industry as a whole is a capital-intensive business that is still in its infancy, and needs continued regulatory support as it scales-up. Investment has been slow and several cellulosic companies have struggled financially. A forthcoming paper by the ICCT and researchers at Johns Hopkins University (in press) analyzes publicly available financial data to show that cellulosic and algal biofuel companies still hold significantly higher investment risk than the stock market as a whole. Investors therefore demand high expected rates of return from these companies. This work suggests that enhancing the value of the second-generation biofuel producer tax credit by allowing companies to transfer it to an investment tax credit and to access the value up-front. A principal challenge to growth facing the second-generation biofuels industry in the US is not technological, but financial. Continuing, stable policy support with well-defined market value is necessary to accelerate the commercialization of this fledgling industry. Based on this research, we recommend that California find ways to increasingly use public funding, as well as complementary fiscal and taxation support, to help accelerate the deployment of commercial-scale advanced biofuels with ultra-low carbon lifecycle emissions.

Advanced biofuels will continue to provide the bulk of carbon reduction in the LCFS program for the immediate future. To support continued commercialization and scale-up, ARB should provide market confidence beyond 2020, for instance through indicative decarbonization targets as suggested above. We also recommend that California recognize the importance of complementary fiscal measures at the State and federal levels, and push for supporting with investment tax credits for second-generation biofuel facilities. To this end, California should also consider mechanisms to increase certainty and bankability of LCFS credit value – and also the potential future value of cap-and-trade credits from low-carbon fuels. This could include using a flexible compliance mechanism to increase policy stability and clarify credit value, and considering mechanisms to front-load LCFS-credit awards for second-generation facilities.

Electric drive

To achieve a long term 50%+ carbon intensity reduction, the LCFS will need to shift from being primarily a biofuel incentive policy to a policy that accelerates the use of near-zero carbon electricity and hydrogen. To do so, we recommend that the LCFS be used to increasingly promote emission reductions from the use of low-carbon electricity and hydrogen in the vehicle fleet. Shifting the LCFS to push for more broad freight-related electrification ideas like electrification of transport refrigeration units, truckstop electrification, port electrification for ships, and perhaps other port operations, would be a positive step (see Yeh et al, 2011; ICF, 2013). Expanding the LCFS framework to include public transportation like high-speed rail that is powered by low-carbon electricity and hydrogen would also be a more comprehensive way to capture the entire transportation system.

We also recommend that ARB work to get more of the value of electricity-related LCFS credit directly to consumers (or fleets, public transit agencies, port operators) that are faced with the investment decision to pay for electric-drive equipment would help the market value proposition and better encourage electric drive sales. This is important as California seeks to move from early adopters to the mainstream consumer market for new advanced electric drive vehicles.

We support California's continuing work to assist in the necessary infrastructure for advancing the deployment of low-carbon fuels. The deployment of ultra low carbon transport energy will be dependent on infrastructure, namely renewable infrastructure in the power sector, charging infrastructure for plug-in electric, fueling infrastructure for hydrogen. The State of California should continue in its robust support for key infrastructure investments with public funds where the market needs support to achieve critical mass. Major, sustained hydrogen refuelling and electricity recharging infrastructure investment in California will continue to be critical in maintaining California's global electric-drive vehicle leadership. Finally we would encourage California to advocate for federal US policy that shifts the Renewable Fuel Standard (RFS) to better encourage electric-drive energy use that is derived from renewable sources. Currently the RFS program is far too restrictive in allowing renewable electricity use to quality for RFS credits, and improvements would help to better align it with the more comprehensive LCFS program (See, e.g., ICCT, 2013; Lutsey 2013a).

Fossil fuels

Along with work to accelerate electric-drive and biofuel deployment, ARB could also demonstrate (and magnify) its leadership in promoting natural gas usage for multi-modal transport and port equipment and liquefied natural gas for ships. We emphasize that ARB should continue to closely track the leading science and most recent data collection efforts on upstream supply chain methane leakage to ensure that its related climate policy to promote natural gas incorporates best available lifecycle emission data. Also, noting California's work to help promote natural gas for trucks for air quality reasons, we recommend that the State seek ways to make sure that natural gas infrastructure systems being built in the near-term can be easily converted to hydrogen refuelling stations to help in the long-term transition to hydrogen-fueled transportation.

Slowing the investment growth in high-carbon fossil fuels is a critical area of importance where California has sought to lead. Regulations and market signals are needed to help the world discriminate between higher- and lower- carbon fossil fuels. California's LCFS is helpful in this regard. Putting transportation fuels in cap-and-trade system could be helpful as well, especially if lifecycle fuel emissions are incorporated. By introducing first High Carbon Intensity Crude Oil screening, and now full assessment of California Average crude oil carbon intensity, CARB has shown leadership on addressing crude oil upstream emissions. However, for now, fuel providers' investment decisions are still only being marginally impacted by the relatively weak investment signals in policy related to oil sands and other unconventional oils with relatively high lifecycle carbon impacts.

The current California Average implementation of LCFS largely separates the cost – and the associated increased carbon – of supplying high-carbon crudes (e.g., oil sands, extra heavy oils) from the company choosing to refine/import them. Using fuel carbon policies to hold regulated companies directly accountable for the lifecycle carbon emissions of the fuels they are selling is increasingly important, especially considering the continued expansion of unconventional high-carbon crude oils (see, e.g., Lutsey, 2013b). We encourage California to work directly with its European colleagues on ways to track, differentiate, and discriminate conventional and unconventional oil based on their relative carbon intensity.

Public info on company carbon burden

In the past, the ARB has stated its commitment to consider a fossil fuel treatment that directly values upstream carbon emissions, and we support that as a principle for future regulatory development. We note that the cap-and-trade and LCFS policies, for example, although helpful, will not be enough to prevent or reduce the influx of high-carbon unconventional crudes like oil sands and extra heavy oils. As mentioned above reducing oil demand through increased efficiency across all the transportation modes is a critically important part of the overall puzzle, along with fuel-based policies. However, noting the difficulty in steering massive private and public investments off of oil and other high carbon fossil fuels, the ICCT is offering a suggestion for California to consider using its science-based approach to help the public better understand this issue and potentially act on that understanding.

Following the various university policies to divest in fossil fuel companies, the ARB could help to make recommendations for public government investments, as well as for citizens, in California about investments in companies that are disproportionately contributing to high carbon emissions. Recent work from the Carbon Tracker initiative spells out which companies hold, and will seek to extract, the majority of fossil fuels and what the ramifications would be for global climate (Carbon Tracker 2011). Many of these companies seek to comply (and sometimes help develop, modify, or legally disrupt progress) on California's climate policies.

The ARB has the technical credibility and the necessary data to play a unique role as an information clearinghouse to facilitate better investment decisions on carbon-intensive companies and their practices in California. Guidance documents that transparently lay out which companies are currently profiting from actions that are inconsistent with California's near- and long-term climate stabilization goals could be useful to provide a market signal for sustainable investments. The ARB could utilize data and companies' compliance responses from its cap-and-trade and LCFS policies to provide a repository of information for state agencies, investment firms, and individuals to act upon. The information could be presented in guidance documents that highlight the relative carbon risk exposure of companies with relatively high carbon investments that are unsustainable over the long term. Going further, the ARB could issue guidelines and recommendations for investments in companies that were making exemplary efforts in leading the way toward a low-carbon future.

Fuels in the emissions inventory

The ICCT also offers a suggestion for California to improve its GHG inventory practices. Nearly every major climate emission inventory and energy data repository that is conducted by government agencies and research organizations (e.g., the US EIA, and IEA) that are used by governments and researchers assumes, and does calculations based upon, tailpipe CO_2 emissions as a direct carbon conversion from combusted petroleum fuels (e.g., based on the low heating values of gasoline, diesel, etc). The ARB lifecycle tools used in analyzing the LCFS fuels make it very clear that transportation fuels have substantially larger climate impacts than simply implied from a carbon balance on the refined fuel. California's extensive lifecycle analysis of transportation fuels is rigorous and well supported.

Therefore, it stands to reason that fuel lifecycle emissions be directly included in ARB's GHG inventory as part of transportation's GHG emissions. Some of the carbon emissions are indeed indirect land use change (e.g., in Brazil), or higher fossil fuel direct emissions outside California (e.g., in Canada), but many are accounted for within the industry sector due to California refineries. Generally, by ARB's accounting, the lifecycle GHG of transportation fuels is over 95 gCO_2e/MJ, whereas GHG inventories (e.g., in EMFAC modeling, US EIA, IEA, etc), count transportation emissions at about 9-10 kg CO_2/gallon of gasoline and diesel fuel or about 68-72 gCO_2e/MJ. Thus, emission inventories routinely undercount transportation's contribution to GHG inventories by approximately 25%.

If an inventory is to include all the known emission activities from California activities, and if these lifecycle emissions are established in the LCFS program, these full lifecycle emissions should also be included in state-wide inventory accounting. As a result, we recommend that California comprehensively calculate a full fuel-cycle accounting in its state GHG emission inventory and apportion these emissions to the transportation sector. Doing so would help to make it clear, for example, that transportation represents a greater share of the overall economy's emissions (i.e., greater than the Plan's 38% in Figure 4). As noted above, the omission of California-related marine and aviation emissions from the inventory also amounts to a substantial undercounting of transportation's GHG emissions. Because these emissions happen due to the activity of the California economy, they too will need to be addressed over the long-term for climate stabilization. Until these steps to correct the inventory are made in simple bar charts, pie charts, and summary tables that show sector GHG emissions and emission reduction potential are corrected, transportation sector opportunities (and risks) will continue to be under-represented.

IV. Short-lived climate pollutants

We applaud California for including short-lived climate pollutants in the draft Scoping Plan First Update. We recognize the valuable precedent this sets within California and internationally toward addressing the climate problems that short-lived pollutants cause.

Our view is that a plan to control short-lived pollutants should have three aims in mind: (a) to reduce near-term climate impacts (b) to complement CO_2 emission control strategies and (c) to realize ancillary co-benefits to public health, agriculture, and economic growth. Control of short-lived pollutants is very effective at reducing near-term climate impacts, particularly the rate at which we are accelerating temperature change today. The latest science also suggests that the successful and timely control of short-lived pollutants increases the odds of limiting future warming to less than 2 degrees Celsius above the pre-industrial period when coupled with ambitious CO_2 control strategies. And short-lived pollutants cause impacts beyond climate change including premature death, crop fertility loss, and economic losses associated with these. These provide strong justification for the proposal the staff has put forward.

The approach suggested, which is to separately account for and investigate short-lived pollutants independent of ongoing planning that is focused on control of carbon dioxide and the other Kyoto gases, is one we support wholeheartedly. This allows ARB staff to focus on the unique role that short-lived pollutants can play in a comprehensive climate mitigation strategy, particularly the near-term climate impacts they cause, and avoids concerns expressed by climate scientists regarding confusion of overall policy goals. We are encouraged by the view expressed by staff to seek guidance from external experts, which we think is important in light of the emerging science in this area.

We believe there is valuable research available that would lead to a robust 2016 plan for short-lived pollutants, but such a plan will require important precedent-setting decisions for how best to account for such pollutants. We encourage staff to seek out experts in this area, and to consider sponsoring a set of workshops and/or establishing an advisory committee to guide the translation of science into policy choices leading up to completion of the 2016 strategy.

We support the Staff decision to shift to Intergovernmental Panel on Climate Change (IPCC) fourth assessment report (AR4) Global Warming Potential estimates, and we note the slight change this made to the 2020 target greenhouse gas limit. We note that the recent September 2013 publication of the IPCC's Fifth Assessment Report further revises these values, including suggestions for metrics and new time horizons. We suggest that staff consider establishing a process for aligning with IPCC values as soon as reasonably feasible in order to maintain a strong linkage between its policies and the best available internationally accepted science.

We support the efforts taken to date on fluorinated gases, and we encourage Staff to continue to seek out all cost-effective and technically feasible hydrofluorocarbons

(HFC) reductions, including regulations on in-use emissions from service and disposal events for vehicles. Staff mentions agreements the US is actively seeking and making with the international community to globally regulate HFC, including a recent agreement with China. We are strong supporters of such agreements and believe that significant reductions will result when such agreements are formalized as an amendment to the Montreal Protocol to regulate HFCs within this international framework. But we also strongly believe that early actions taken by California and other nations independent of a global framework are important since we may not expect to see any trickle down from a global agreement for a decade or more. We believe early actions can reduce emissions much more rapidly in California by forcing the early development of alternative refrigerants and the infrastructure that supports them. We also think actions to limit in-use refrigerants, including refrigerant banks, are vitally important and are not likely to be captured by a global agreement. Therefore it is important that California continue to take actions on HFCs independent of a global agreement.

On methane emissions, we note that there are lingering concerns about the release of methane during oil and gas exploration, as well as leakage during transport of natural gas and during regular operation of natural gas-powered vehicles. These methane emissions, to the extent unchecked, jeopardize the potential for natural gas-derived fuels to lead to a lower carbon transportation sector. We encourage ARB to evaluate, based on new emerging science on methane leakage, whether methane emissions are properly accounted for in its accounting system for the LCFS. Better data on methane emissions are critical in (a) understanding whether natural gas vehicles can be a substantial part of any mid-term transportation climate mitigation scenario, and (b) identifying where there might be cost-effective measures to reduce methane leakage from natural gas. We also request that ARB investigate and consider whether black carbon emissions during flaring and other lifecycle fuel processes are accounted for in LCFS fuelcycle accounting.

On black carbon, we support the inclusion of this pollutant in the California’s climate emissions inventories. California has been an unexpected leader in diesel black carbon control since the 1960s, owing to its regulations to reduce diesel particulate matter. We applaud the efforts of the ARB Research Division over many years to support large-scale investigation into the historical benefit of diesel black carbon mitigation in the state. We also commend the contributions staff has made within the research community to a better global understanding of black carbon emissions measurement, inventory methods, and testing for both vehicles and international shipping.

We encourage ARB identify all cost-effective options and adopt regulations to control diesel black carbon to realize its potential to simultaneously prodcue strong health and climate benefits. We also encourage staff to investigate the extent to which accounting for the societal benefits of black carbon control and climate mitigation might actually motivate more aggressive actions to control diesel and other mobile sources of black carbon – including sources already regulated. We advise staff to support research into the climate benefits of control of other black carbon sources, which may emit more co-pollutants whose light-reflecting properties and interaction with clouds may complicate and potentially offset any warming caused by black carbon. However, we advise against including short-lived pollutants in the existing cap-and-trade program at this time. We believe staff have the tools at their disposal to deal properly with these pollutants without the cap-and-trade program.

V. Cooperation and the leadership effect

From its earliest climate mitigation days, the state of California contended with arguments from opponents of its carbon reduction policies that policies were unproven or too narrow from the perspective of overall global climate change. The State has, however, gone far beyond its first climate mitigation steps to expand the climate action solution space with innovative new policy tools, especially for vehicles and fuels, as well as throughout all the major sectors of the economy. Further, California has greatly multiplied its climate mitigation impact and strengthened global policies through its continued international dialogue and its direct outreach efforts. These outreach efforts have effectively leveraged California's work to get similar climate mitigation action elsewhere, domestically and internationally. In do doing, California's has defined the concept of the "leadership effect" with its climate policy innovation and relentless learning and sharing about its practices. We support California's efforts to continue its international, federal, and state outreach in order to help multiply the climate benefits of all of its hard won successes from the initial Scoping Plan in 2008 through to today.

International leadership

Greenhouse gas emissions are global. There are common activities across the globe that cause the climate emissions, society is equally impacted by emissions from every other jurisdiction, and the solutions that are applicable in California are almost entirely applicable elsewhere. So California has rightly and aggressively sought to leverage its mitigation efforts with other states, nations, and regions. Many climate policy opponents routinely state that individual "bottom-up" unilateral actions are small compared to the global challenge of climate change. California has proved the value of its individual actions, its leadership effect to provoke similar action elsewhere, and collaborative action with other governments, time and time again.

California has done an excellent job leveraging its efforts with collaborative work with federal agencies, multi-lateral agreements with countries and sub-national agencies. One region where California's leadership plays an important and growing role is China, the world's largest greenhouse gas emitter and home to the world's largest automobile market. The challenges China faces in solving its environmental problems are enormous. In the face of these challenges, China's leadership has demonstrated a dedicated commitment to pursuing world-class technical and regulatory solutions. The Chinese government's strong willingness to engage in environmental cooperation with

California is a clear sign that China recognizes California's unique leadership role in crafting many of the pioneering policies to help spur the technical solutions. China has been particularly impressed with California's long-term economic growth combined with its deep emissions reductions.

2013 has been a landmark year for establishing formal California-China cooperation on air quality improvement and climate change. In April, Governor Brown signed an unprecedented agreement with China's national Ministry of Environmental Protection to collaborate on air quality improvement. This was followed a few months later in September with a Memorandum of Understanding signed with China's National Development and Reform Commission (NDRC) on climate change mitigation. These agreements have been further complemented this year with additional agreements at the provincial (Guangdong) and municipal (Shenzhen) levels. These agreements are already bearing fruit for both sides in the form of detailed technical training sessions, trade agreements for clean vehicle technologies, and more.

Specifically, we see immediate synergies in a number of areas between California and China, where enhanced and more targeted collaboration between the two governments will deliver commensurate benefits in low-carbon technology deployment, and climate benefits. First, experience sharing to promote advanced technology vehicles (with the Ministry of Industry and Information Technology [MIIT] and NDRC) will help accelerate electric-drive technology. Second, work toward stringent fuel efficiency standards for light- and heavy-duty vehicles for in the mid-term (2020-2025) between California and MIIT will ensure more aligned, lower cost deployment for efficiency technologies in both regions. In China, economy-wide national and regional GHG targets have not been formally translated to the transportation sector-specific goals or GHG standards for various vehicle fleets, but are only reflected as vehicle efficiency regulations. Improving efficiency and reducing emissions from heavy commercial trucks are also in line with the recent bilateral collaboration between the US and China at the national level. Finally, increased collaboration on lower carbon fuel mandates and incentives (with the NDRC) will help to reduce fuel carbon intensity in both places over the long-term.

Federal cooperation

The California Air Resources Board has written the book on how to simultaneously lead *and* jointly cooperate with the federal agencies that hold similar or related authority on vehicles, fuels, and greenhouse gas emissions. The relationship has served extremely well in terms of helping explore policies at the California state level to progressively accelerate technology deployment and to also allow other states to learn from and adopt California's policies. The relationship has also helped to develop federal policies where major industries need more clear national-level regulations to guide their long-term investment decisions.

Table 4 provides a simplistic itemization of federal and California policies that promote a low carbon transportation sector. The table provides a listing of policies that are likely to be important in achieving a long-term climate stabilization scenario for the transportation sector. The table highlights where major policies have been implemented in California, as well as at the federal US level. Although we have pointed out many areas above where California has provided an excellent blueprint for how to dramatically reduce the climate impact of the transportation sector, the table makes it clear there far more additional policy actions that likely will be needed to put the transportation sector on a path that is consistent with climate stabilization. As a result, we strongly encourage the State of California and federal agencies continue their successful work to develop leading low-carbon vehicle and fuel policies.

We have highlighted a number of areas throughout these comments where California and US policymakers would stand to gain from collaboration, aligned policies, and technical exchanges. Here, we highlight several areas where aligned policy action at the California and federal levels would be especially beneficial for GHG mitigation efforts. First, collaboration on replacement tire standards is an area where both California and federal regulators should have high motivation and also have regulatory authority to accelerate the deployment of cost-effective tire technologies for substantial GHG benefit. Second, revisions, additions, and complementary fiscal measures in California and federal US fuel policy could be adopted to better accelerate electric-drive vehicles. California's continued outreach to other states, and increased advocacy for federal government involvement in electric-drive consumer and infrastructure development is well warranted. Third, dramatic private infrastructure investments will be needed for advanced low-carbon biofuels, so complementary fiscal and taxation support should be investigated to help ensure the success of the California LCFS and federal RFS programs. Fourth, California could help its public investment fund managers and residents better understand which companies have carbon holdings and fuel practices that are inconsistent with long-term climate stabilization with increased public information and guidance documents. Finally, more comprehensive consideration of aviation and marine emissions in inventories, as well as research into the potential carbon mitigation opportunities for these two modes, would be an excellent area for federal and California policymakers to team up and exert global leadership.

Table 4. Comparison of California and US transportation climate mitigation policies

Area	Policy action	California	United States
Light-duty vehicle efficiency	GHG regulatory standard for new vehicles through 2025	✓	✓
	Accelerate deployment of electric-drive vehicles with mandatory requirements	✓	No
	Low rolling resistance tire regulation for replacement tires	No	No
Heavy duty vehicle efficiency	GHG regulatory standard for new vehicles through 2018	✓	✓
	In-progress work and commitment to develop “Phase 2” 2019+ GHG standards	✓	✓
	Tractor trailer GHG regulation to accelerate efficiency technology for existing fleet	✓	No
	Low rolling resistance tire regulation for replacement tires	✓	No
	Accelerate deployment of electric-drive vehicles with mandatory requirements	No	No
Alternative fuel policy	Low carbon fuel performance standard promotes greater use of lower carbon fuels (biofuels, electricity, hydrogen)	✓	No
	Complementary fiscal policies to support electric drive	✓	✓
	Requirements for advanced biofuels with ultra-low carbon fuels	No	✓
	Complementary fiscal policies to provide greater support for advanced biofuel commercialization	No	No
	Cap-and-Trade promotes reduced upstream carbon emissions of transportation fuels	✓	No
	Public infrastructure support for hydrogen refuelling stations	✓	No
	Policy to strongly discourage investment in high-carbon transportation fuels	No	No
	Guidance document for public investment funds and citizens on low-carbon leaders and companies with high-carbon risk exposure	No	No
Marine	Inventory inclusion of shipping GHG emissions	No	No
	Inclusion of marine fuels in regulatory policies to reduce fuel carbon intensity	No	No
	Port electrification requirements	✓	No
	New ship efficiency (“EEDI”)	✓	✓
	In-use ship efficiency policy	No	No
Aviation	Inclusion of aviation GHG emissions in inventory	No	No
	Inclusion of aviation fuels in regulatory policies to reduce fuel carbon intensity	No	No
	New aircraft efficiency policy	No	No
	In-use aircraft GHG mitigation policy	No	No
Black carbon	Inventory adopting IPCC climate practices	✓	No
	Best practice particulate / BC controls for on-road vehicles	✓	✓
	Best practice particulate / BC controls for off-road mobile sources	No	No

GHG = greenhouse gas; BC = black carbon

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