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New York's Clean Fuel Future

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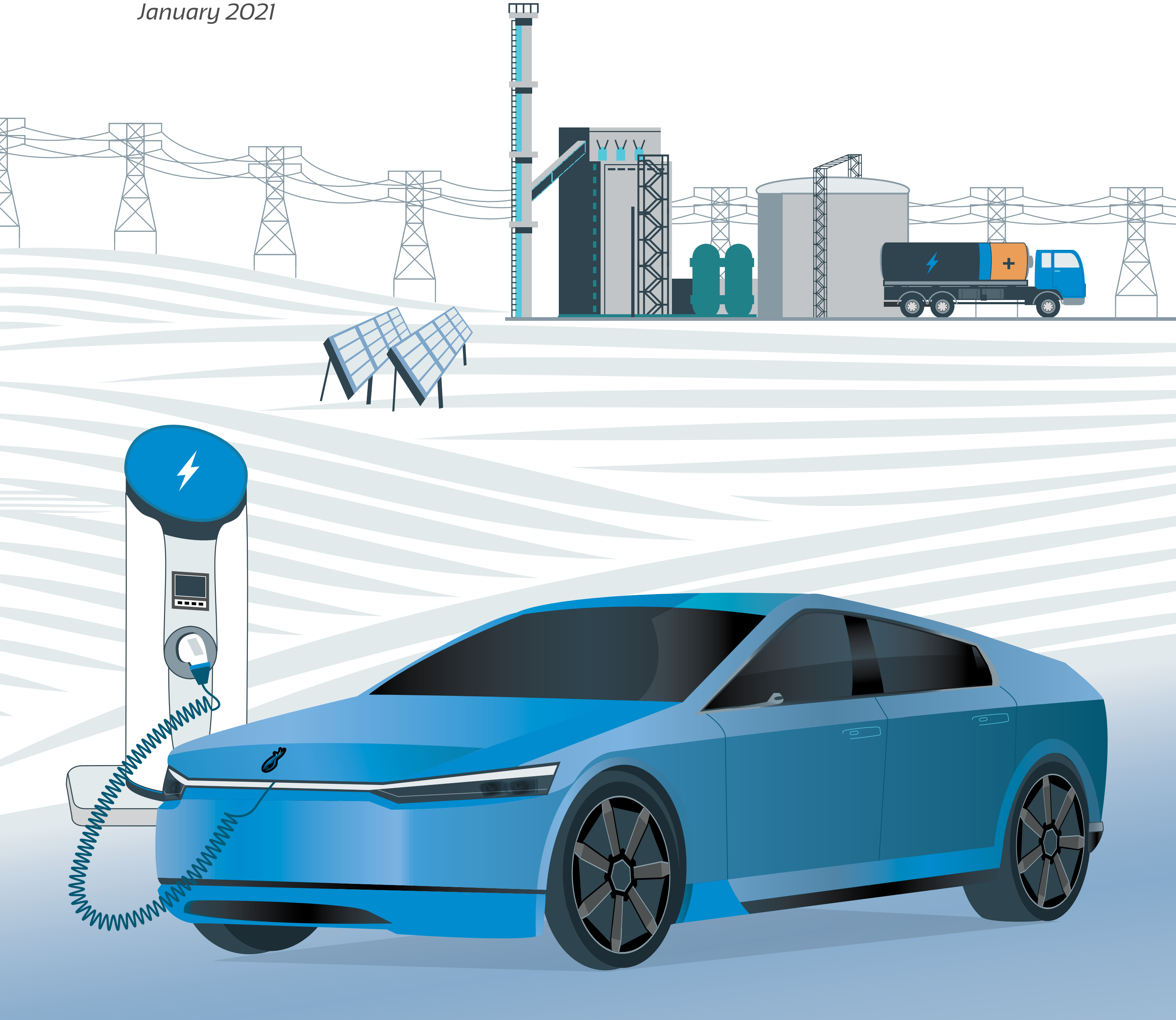

Acknowledgments

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1. Summary

For ten years, the Low Carbon Fuel Standard in California (CA-LCFS) has supported the replacement of fossil energy for transportation with alternative fuels identified as having lower carbon intensities. Despite challenges along the way, the program now delivers a strong value signal, and California is looking at innovations in the standard to enhance its role in supporting the deployment of electric drive vehicles and infrastructure. With similar climate goals and similar objectives to expend the electric vehicle fleet, the State of New York is considering the adoption of its own NY-LCFS, with a suggested target to deliver 20% carbon intensity reduction in New York’s on-road transportation energy supply by 2030.

This report details two scenarios for New York to achieve that 20% carbon intensity reduction goal, assuming that an NY-LCFS would be similar to the California program. Both scenarios show a large contribution to carbon intensity reductions delivered through passenger vehicle electrification. One of them, the ‘*balanced*’ scenario, also includes significant increases in carbon savings delivered by liquid and gaseous alternative fuels (renewable natural gas, ethanol, biodiesel and renewable diesel). The second, the ‘*high ZEV*’ scenario, has even more rapid electric vehicle deployment for both passenger vehicles and medium- and heavy-duty vehicles, and therefore requires less of an increase in other alternative fuel supply. Both scenarios should be achievable, even recognizing competition from other programs (including the California program) for alternative fuel resources. Figure A shows the contributions of the main lower carbon intensity pathways to achieving the target under the *balanced* scenario.

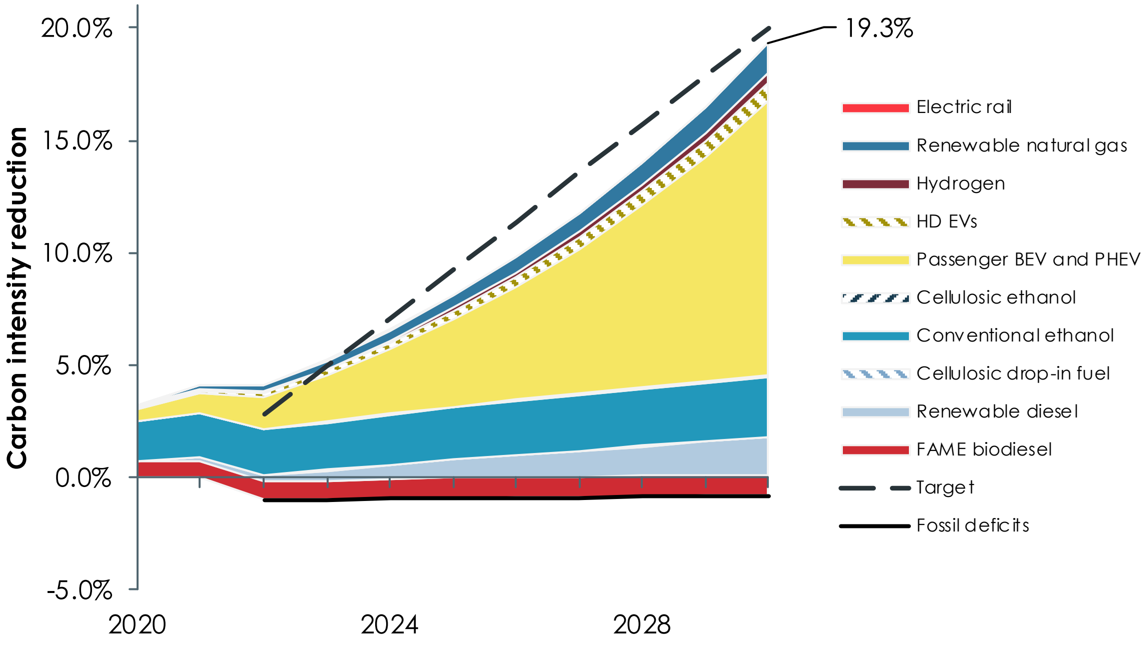

Figure A ***Balanced*** **scenario to deliver 20% carbon intensity reduction by 2030**

As a performance-based measure, a low carbon fuel standard requires higher carbon intensity fuel providers to supply lower carbon intensity fuels or to buy credits from lower carbon intensity fuel providers. Based on financial assumptions detailed in the report, by 2030 NY-LCFS credits for electric vehicle charging in the *balanced* scenario could deliver $900 million of revenue to support electric vehicle deployment and charging infrastructure. Hundreds of millions of dollars of this credit revenue could be made available specifically to support electrification in disadvantaged communities if New York State adopted measures recently proposed for this purpose in California.

As well as climate benefits, an NY-LCFS would deliver improvements in air quality. These arise primarily due to lower particulate matter (PM) and NOx emissions associated with increased use of renewable diesel and biodiesel[1], and electricity. The indicative assessment in this report of the monetized value of these health benefits suggests a cumulative value of nearly $1 billion by 2030.

The modeled scenarios presented here are not intended as predictions, but as indicative examples of how the goals of a NY-LCFS could be delivered. A successful low carbon fuel standard program requires effective implementation, and a stable value proposition from credit generation to support investment. In California, innovative measures are being introduced to use CA-LCFS credit revenue more effectively as a lever to drive electrification, including electric vehicle purchase rebates and capacity credits for hydrogen refueling and fast charging infrastructure, and New York State should give strong consideration to introducing such mechanisms if and when an NY-LCFS is adopted.

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[1] Biodiesel can lead to increase NOx emissions but in the modeling these are compensated by reductions due to renewable diesel blending.

Contents

Glossary

LCFS – Low Carbon Fuel Standard

CA-LCFS – California Low Carbon Fuel Standard

NY-LCFS – New York Low Carbon Fuel Standard

EV – Electric Vehicle

EV 100/200/300 – Electric vehicle with range of 100/200/300 miles

BEV – battery electric vehicle

FCV – (hydrogen) fuel cell vehicle

PHEV – plug-in hybrid vehicle

ZEV – zero emission vehicles (BEVs, PHEVs and FCVs)

ICE – Internal Combustion Engine

HDV – heavy duty vehicle

MDV – medium duty Vehicle

PV – passenger vehicle

Units

gCO_2e/MJ - grams carbon dioxide equivalent per megajoule of energy (lower heating value)

MJ – megajoule (lower heating value unless otherwise indicated)

mmDGE – million diesel equivalent gallons

tCO_2e – metric tons carbon dioxide equivalent

2. Introduction

In 2019, bills were introduced in the New York State Assembly (Woerner, 2019) and Senate (Parker, 2019) with the goal of introducing a "low carbon fuel standard" (NY-LCFS) that would mandate a 20% reduction in the greenhouse gas intensity of New York on-road transportation fuel by 2030. The bills call for this standard to have regard to existing low carbon fuel standards in other states, notably California:

> *The low carbon fuel standard shall take into consideration the low carbon fuel standard adopted in California and other states, [and] may rely upon the carbon intensity values established for transportation fuels in such states.*

Such a NY-LCFS would apply to all providers of transportation fuels in New York State, with greenhouse gas intensity values assessed on a full lifecycle basis, "including direct emissions and significant indirect emissions". Regulations establishing the NY-LCFS should be promulgated within 24 months of the passage of the bills into law. Both bills are currently still at the Committee stage.

2.1. Low carbon fuel standards (LCFSs)

A LCFS is a regulation intended to create a performance-based framework for the reduction of greenhouse gas emissions from the transportation sector (Farrell, Sperling, Arons, et al., 2007). Conventional transportation fuels (primarily gasoline and diesel) release carbon dioxide as a product of their combustion, which contributes to global heating. There are also emissions of carbon dioxide (and potentially other greenhouse gases such as methane) associated with extracting, refining and distributing fossil fuels (El-Houjeiri, Brandt, & Duffy, 2013). The sum[2] of the greenhouse gas emissions from combustion and the greenhouse gas emissions associated with fuel production is the *carbon intensity* of the fuel. If fossil fuels can be replaced by alternative energy sources with lower lifecycle emissions, then the contribution of transportation to global heating may be mitigated.

A number of alternative energy sources are available for transportation that may have lower lifecycle greenhouse gas intensity than the conventional liquid fossil alternatives. These include liquid biofuels and electrofuels[3] that can be used in conventional internal combustion engines (ICEs), fossil and renewable natural gas that can be used in vehicles with converted engines, and hydrogen and electricity that can be used in electric drive vehicles (battery electric vehicles, BEVs; plug-in hybrid electric vehicles, PHEVS; fuel cell vehicles, FCVs). The greenhouse gases associated with producing and using these fuels can be assessed through lifecycle analysis (LCA), providing a basis to identify how much better they are for the climate than the conventional fossil alternatives.

An LCFS uses these lifecycle greenhouse gas intensity ratings as a metric to assess the performance of each transportation fuel against a greenhouse gas intensity target that reduces over time. Supplying fuels such as gasoline and diesel that have higher carbon intensities than the standard generates *deficits*. Supplying fuels with lower GHG intensities than the target

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[2] For a unit of energy supplied.

[3] Cf. Malins (2017).

generates *credits*. Fuel suppliers are required under an LCFS to cancel out the deficits they have accrued during the year by redeeming an equivalent number of credits. Companies supplying fossil fuels to the market become the obligated parties under the standard and must report volumes of fuel supplied so that deficits can be calculated, while companies supplying lower carbon intensity fuels may register to receive credits. In many cases, the same company may supply both fossil and alternative fuels, in which case both credits and deficits could be generated.

By using LCA-based carbon intensity values as a basis to set the rate at which credits are awarded, the LCFS framework seeks to reward fuels in proportion to the climate benefit they deliver – it is a performance-based standard. In this way, LCFSs seek to emulate the characteristics of other successful performance-based standards such as vehicle efficiency and emissions standards[4]. By providing rewards in proportion to the climate benefit of each compliance option, the LCFS is designed to allow the market to choose the most cost-effective way to deliver decarbonization. This system of performance based incentives is not perfect – there are complexities in the system such as uncertainty in the LCA assessment and challenges in weighting the value of future emissions reductions that do not have a simple answer – but it provides a more nuanced approach than is possible with simpler renewable energy mandates such as the federal Renewable Fuel Standard (RFS). The LCFS framework also lends itself to providing incentives for a wider array of climate solutions than are covered in biofuel mandates like the RFS. In the California LCFS, for instance, as well as the fuel options mentioned above carbon savings can be rewarded in the refining industry and in oil extraction, and in non-road transportation including light rail and aviation.

Under an LCFS, a market is created to allow the trading of credits between companies. In this way, suppliers of fossil fuels are able to obtain enough credits to meet their obligations and avoid fines or prosecution, while suppliers of lower carbon intensity alternative fuels are able to develop an additional revenue stream to support fuel production and supply. In the case of electricity supplied for home charging of electric vehicles, public utilities receive credits. Under the California LCFS, these utilities have an obligation to return the value of those credits to electric vehicle owners. Programs have been introduced to allow the value of LCFS credits to be used to support vehicle purchase rebates.

The value of credits is set by the market. If the number of credits being generated is large compared to the number of deficits, the value of credits can be expected to be lower. If, on the other hand, there are not enough credits available for all suppliers to meet their obligations then prices can be expected to increase. The risk of disrupting fuel markets through very high credit prices can be managed through the use of a *cost containment mechanism* (also sometimes referred to as an alternative compliance mechanism or a safety valve). Under the California LCFS, this has taken the form of a 'credit clearance market' to ensure that any remaining credits are sold at an agreed price if the market is short, and the possibility to build up credit debts to be paid back later if insufficient credits are available to meet obligations. In 2019, this system created an effective LCFS credit price cap of $2135 per tonne of carbon dioxide abatement ($/tCO2e). Moving forwards, the CA-LCFS has been amended to allow future base charging credits to be brought forward to meet any outstanding obligations, preventing debt build up.

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[4] Corporate Average Fuel Economy, or CAFE, standards and greenhouse gas and criteria pollutant emission standards.

[5] Calculated by adding inflation to $200 in 2016 dollars.

Additional flexibility may be given to obligated parties by allowing *banking* of credits from one year to another. This means that if a party has spare credits at the end of the year above and beyond those needed to cancel out any deficits, these credits may be held for later use. In this way, over-compliance early in the program can be used to meet obligations later in the program. Such a strategy may be especially advisable for companies if they expect that compliance with targets will become more difficult as the program progresses.

2.2. The California experience

The California LCFS (CA-LCFS) started implementation in 2010 and was a highly innovative regulatory framework for its time. Implementing the CA-LCFS required the development of existing LCA tools (cf. California Air Resources Board, 2014) and the creation of new analytical frameworks to provide indications of the carbon intensity associated with indirect land use change (ILUC, cf. Hertel et al., 2010) and to assess variations in the carbon intensity of oil extraction (cf. El-Houjeiri et al., 2013). Successful implementation has required a large team of committed and talented staff at the California Air Resources Board, and the work done in California over the last decade provides a strong starting point for other states considering similar policies – Oregon and the Canadian province of British Columbia have both implemented similar programs following California's lead with much smaller administrative teams.

The standard has faced a continuous stream of legal challenges on various grounds, supported by parties concerned that its implementation was against their financial interest, but has been successfully defended[6] due to its strong legal foundation. Legal and political uncertainty about the long-term future of the standard, coupled with relatively unstretching compliance standards in the early years of the 2010s, led to low credit prices in the first half of the decade. More recently, however, prices have risen and stabilized just below the cap price set by the cost compliance mechanism of the credit clearance market, as seen in Figure 1. This provides a good example of how the combination of challenging compliance targets and a defined price cap can create value certainty for alternative fuel suppliers. Without a cost containment mechanism, the credit price could go higher (perhaps much higher). In principle high prices would provide additional potential revenue for alternative fuel suppliers, but excessive credit prices would create political uncertainty and thus may perversely serve to inhibit long-term investments (Malins, 2018a).

Despite all the legal wrangling, the CA-LCFS has remained in place and reportable carbon emissions reductions have steadily increased. Figure 2 shows the evolution of carbon credit generation from 2011 through to 2018. In the first compliance years of the CA-LCFS, credit generation was dominated by the existing use of first-generation ethanol to meet the RFS and as an octane enhancer for gasoline. This was soon complemented by increasing generation of credits through the supply of biodiesel and renewable diesel, as well as a contribution from renewable natural gas. The credit generation from biofuels has increased through the decade due to a combination of higher volumes supplied and lower reported carbon intensities. The CA-LCFS has both encouraged California fuel suppliers to seek out lower carbon intensity sources of ethanol and encouraged ethanol manufacturers to improve their efficiency so that they can report lower carbon intensities. The most recent significant addition to the credit generation profile is the increasing role of electricity.

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[6] E.g. https://www.argusmedia.com/en/news/1831137-appeals-court-upholds-california-lcfs-again

Figure 1. **Reported CA-LCFS credit prices**

Source: https://ww3.arb.ca.gov/fuels/lcfs/credit/lrtweeklycreditreports.htm

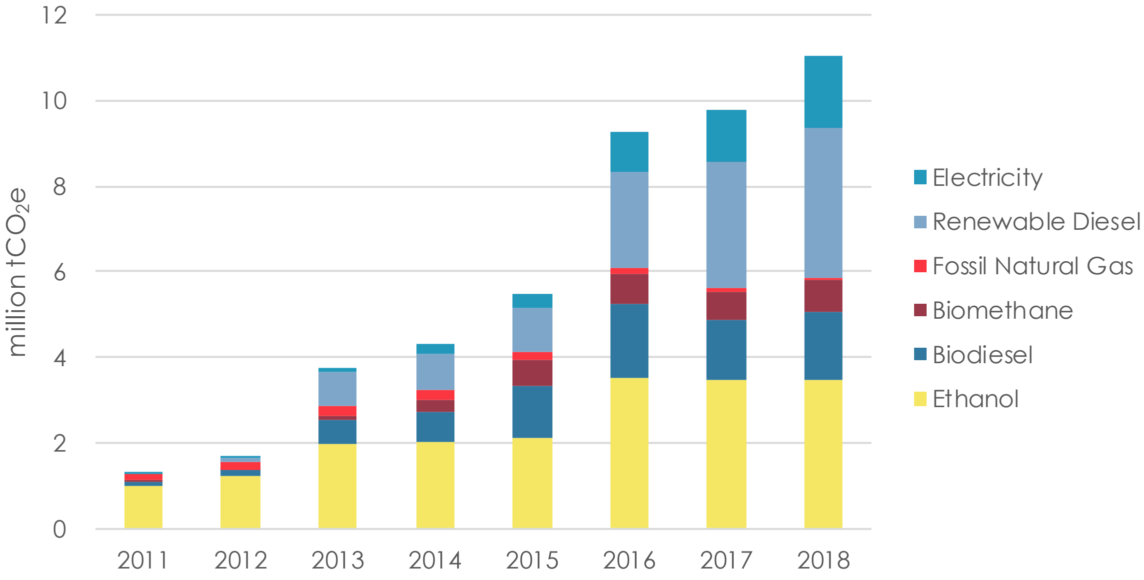

Figure 2. **Carbon emission credits generated under the CA-LCFS**

Source: https://ww3.arb.ca.gov/fuels/lcfs/dashboard/dashboard.htm

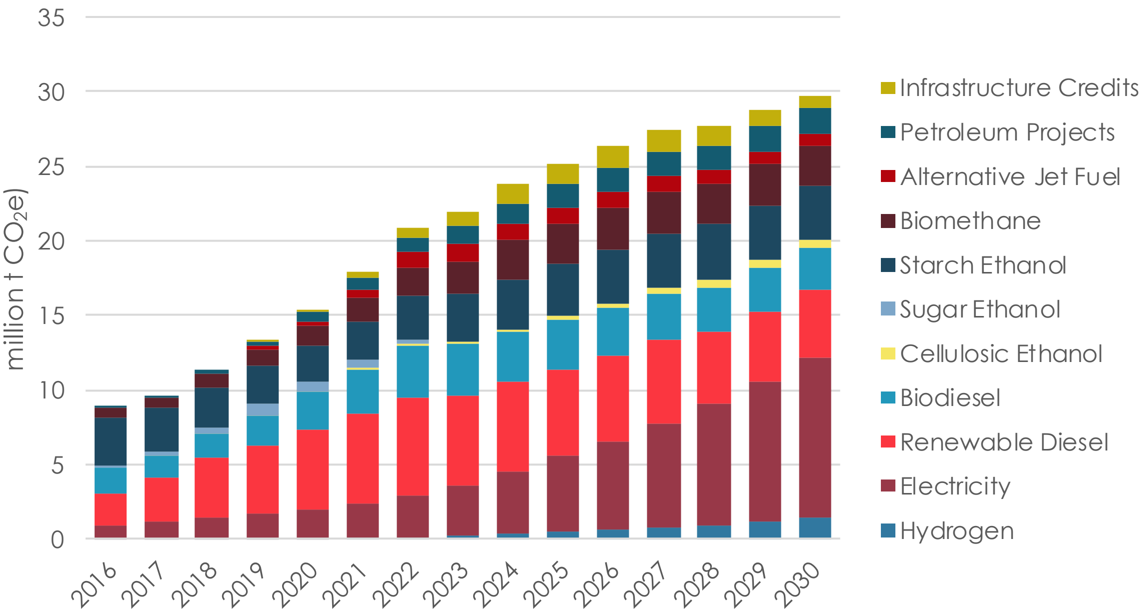

Figure 3. Credit generation in the California Air Resources Board 'low demand, high ZEV' scenario for delivering 20% carbon intensity reduction by 2030

Source: California Air Resources Board (2018c)

With a reported 600,000 plug-in electric vehicles on the road in California[7] and a state target to reach 1.5 million ZEVs by 2025, growth in the EV fleet will be a major contributor to meeting CA-LCFS targets over the coming decade (California Air Resources Board, 2018c; Malins, 2018b). As shown in Figure 3, in illustrative compliance scenarios with high ZEV penetration rates electricity becomes the largest single source of CA-LCFS compliance credits in the second half of the 2020s.

2.3. About this report

In this report, we use an LCFS credit supply model developed for previous work with respect to LCFSs in states on the Pacific Coast to present scenarios to deliver a 20% carbon intensity reduction for New York State on-road transportation by 2030. We also discuss potential costs and benefits of adopting an NY-LCFS and regulatory options to maximize the effectiveness of a standard. The scenarios should be understood as examples, not as predictions – a central precept of the LCFS as a regulatory tool is that because it is performance- and market-based, the market has many options available to deliver compliance. Just as in California the pathways now delivering carbon savings are not necessarily those predicted in modeling when the standard was introduced, we freely acknowledge that in New York the realized carbon savings pathway may be quite different to what is modeled here. We also note that, in part because an NY-LCFS is not yet in place, there is less data available about low carbon fuel

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[7] https://www.sfchronicle.com/climate/article/Californians-are-buying-up-electric-cars-But-14447810.php

supply in New York than there is in California. We acknowledge that there may be elements of our baseline model for New York State that are not yet well characterized, for instance where we have assumed national average values for biodiesel blends and where we have made assumptions about the fraction of natural gas supplied for transportation in New York that is used in vehicles. To the best of our knowledge, this study is one of the first, if not the first, to attempt to model compliance options under an NY-LCFS. We hope that, notwithstanding limitations in the baseline data, this report will help inform policy makers considering the adoption of the LCFS bills. We look forward to seeing more refined and detailed studies become available as an NY-LCFS moves towards implementation.

2.3.i) *Presentation of data*

In this report, as in previous work with this model (Malins, 2018b, 2019; Malins et al., 2015), the scenario results are primarily presented as stacked area charts showing the contributions of each lower carbon fuel supply pathway to delivering the targeted carbon intensity reduction against the baseline (e.g. Figure 4).

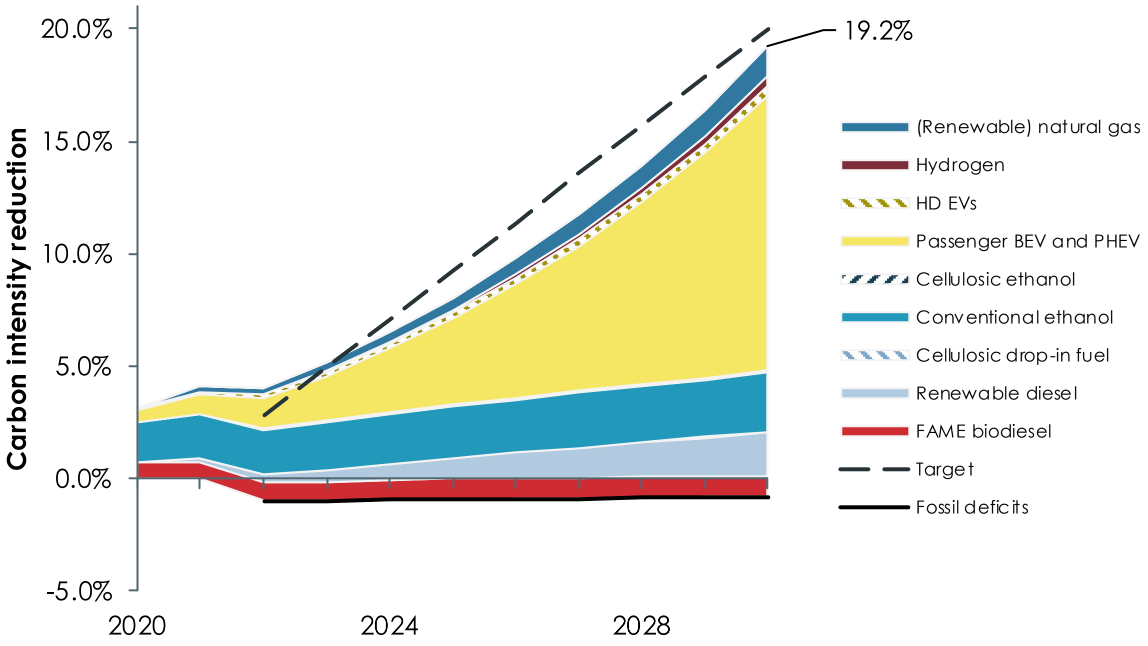

Figure 4. Example: scenario results presented in terms of carbon intensity reduction against baseline

It should be noted that credits are awarded in existing low carbon fuel standards based on the difference between the carbon intensity of the energy supplied[8] and the compliance requirement for that year (which reduces over time), rather than based on the difference between the carbon intensity of the energy supplied and the baseline fuel carbon intensity

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[8] Adjusted in line with an energy efficiency ratio where appropriate, e.g. for

(which is generally static). The carbon intensity savings against the baseline illustrated in these charts are therefore not exactly proportional to the credit generation for each compliance option (although the contributions to credit generation are similar to the contributions to carbon intensity reduction). Also note that the stacked area chart actually starts slightly below the x-axis, at the line marked 'fossil deficits'. In the CA-LCFS, some supply of ethanol is included in the assessment of the gasoline baseline, and so fossil gasoline blendstock (RBOB[9]) has a carbon intensity higher than the baseline carbon intensity of the gasoline pool. This is shown as these 'extra' fossil deficits that must be compensated in order to meet the overall carbon intensity reduction target.

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[9] Reformulated blendstock for oxygenate blending.

3. Supporting electrification

Electrification, initially of passenger vehicles and increasingly of commercial vehicles too, is anticipated to be one of the most important pathways to reduce the carbon intensity of transportation in the United States. The Alternative Fuels Data Centre[10] lists a number of current policies encouraging the switch to electric vehicles in New York State, including plug-in electric vehicle rebates of up to $2,000, heavy duty alternative fuel vehicle purchase vouchers of up to $185,000, and incentives targeted at infrastructure development. Given that electric vehicles are expected to generate a significant fraction of compliance credits under any NY-LCFS, could these credits be leveraged to complement, enhance or replace these existing measures?

Low carbon fuel standards are conceived as performance-based regulations, under which carbon reduction technologies competing with each other on climate-merit alone. The basic mechanism to create this competition is the establishment of carbon intensity values and the creation of an LCFS credit market. In reality, however, the LCFS credit market alone may be more effective as an incentive for some technologies than others, even when they deliver the same reportable climate benefits. This might be because of the need for investment – credit price uncertainty is more of a challenge for novel technologies in need of hundreds of millions of dollars of capital expenditure than it is for existing biodiesel plants. It might also relate to split incentives, if important decisions that affect credit generation are made by parties with no exposure to LCFS credit prices. For example, under the CA-LCFS base charging credits for passenger electric vehicles have been awarded to electric utilities, but the utilities do not directly control rates of electric vehicle purchasing. In short, the economic ideal of a market-based measure may show some limitations when exposed to the exigencies of real markets with imperfect exchange of information.

Both of these issues can be seen in the case of expanding the electric vehicle fleet. Increasing electric vehicle sales requires capital investments from car manufacturers to bring vehicles to market, and at a smaller scale it requires vehicle purchasers to be prepared to invest in buying electric vehicles that are (for now) more expensive than conventional alternatives. Individuals and even fleet managers making vehicle purchase decisions cannot be expected to have the same understanding of an LCFS program and its potential value proposition as liquid fuel suppliers and alternative fuel producers.

Under the CA-LCFS, there is also a clear division between the vehicle purchasers making the investment decision and the electric utilities (referred to as ‘LSEs’, load serving entities) that receive the CA-LCFS credits for residential electric vehicle charging. If home charging credits were awarded to electric utilities without any regulatory conditions, it would not be guaranteed that electric vehicle users would receive any direct benefit (as opposed to having the value returned to all electricity consumers in rate reductions or treated as a windfall profit). There is therefore a requirement under CA-LCFS that, “The LSE must use all [LCFS] credit proceeds to benefit current or future EV drivers in California”[11]. Even so, guidance is needed from the utilities and/or from the State in order to help drivers understand what the value from LCFS credits means for them. Value could be returned through reduced electricity prices, support

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[10] https://afdc.energy.gov/fuels/laws/ELEC?state=NY

[11] Barclays official California Code of Regulations §95491 (d)(3)(A)2, https://govt.westlaw.com/calregs/Document/I2A02D2C878AF4B4EAC5B2A4AEDE6825B.

for vehicle purchases, support for at-home charger purchases, or support for additional non-residential charging infrastructure. Without active programs to raise awareness of the potential value proposition from an LCFS program, it is unlikely to have a strong influence on purchase decisions.

California has recognized that in the past decade LCFS has not been a strong driver of transport electrification and is therefore introducing a state-wide point of sale rebate program to be funded by CA-LCFS credits generated by home recharging of electric vehicles.[12] Shifting a significant fraction of the CA-LCFS credit value generated by electric vehicles into point of sale rebates acknowledges that such rebates are likely to have more impact on vehicle purchase decisions than would the promise of marginal future savings on electricity prices. Additional measures have also been introduced to support infrastructure development for electric drive vehicles.

3.1. Vehicle purchase rebates

Using LCFS credit value to support purchase rebates on electric vehicles is a way to turn an uncertain future credit value into a defined immediate benefit for consumers considering electric vehicle purchases. Given LCFS credit prices of around \$100 /tCO_2e, it should be possible to support rebates of thousands of dollars per passenger vehicle, comparable to existing state level EV purchase incentives (Malins, 2019). Currently, New York State offers rebates of up to \$2,000 for plug-in passenger electric vehicles for private customers and up to \$5,000 for municipal ZEV purchases.

The value of rebate that could be funded by LCFS credit revenue is sensitive to design of the policy, the requirements placed on suppliers of electricity for vehicle charging, the way that future credit generation is treated, and of course to the price of LCFS credits. It is also sensitive to the rate of ZEV deployment (if a large existing ZEV fleet supports a small number of additional sales, the potential rebate would be larger than if a small existing fleet supports a large number of new sales). Finally, the actual size of rebates offered in practice will depend on the fraction of LCFS credit revenue that is committed to rebates as opposed to other programs, and on whether it is possible to bring forward the expected value of future credit generation when setting the level of rebates.

To illustrate the sensitivity of rebate values to design choices, we have calculated the potential rebate available from base credit revenues for three cases under the 'balanced' LCFS scenario described below, assuming that 80% of charging is base charging[13]. For simplicity, we have not considered the case of plug-in hybrid vehicles. We have considered rebates for both passenger and medium/heavy duty vehicles. While the assumption of 80% base charging may be inappropriate for commercial fleets, the calculation at least gives an indication of the value that could be generated by medium/heavy duty ZEVs. Rebate values are based on 'typical' annual activity and energy consumption for each vehicle type in the VISION model (explained in more detail below in the section on 'The credit supply model'). Assumed average credit prices each year are set based on the calculation described below in the section on 'Analysis of costs implications'.

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[12] Barclays official California Code of Regulations §95483 (c)(1)(A)1, https://govt.westlaw.com/calregs/Document/I791DCD16983942E0B343397F26C6C023

[13] https://www.energy.gov/eere/electricvehicles/charging-home

The three rebate options considered are:

1. Rebates offered to new vehicle purchases based on the value of base credits generated in the previous year (‘last year’);
2. Rebates offered to new vehicle purchases based on the value of base credits expected to be generated in the current year (‘current year’);
3. Rebates offered to new vehicle purchases based on expected credit generation from ten years of operation, at current credit value (‘ten years’).

In the first two cases, the value offered would be based on credit generation by all vehicles including EVs already on the road. In the third case, the value of the rebate would be predicated on expected activity by the vehicle sold. This could be implemented by allowing the regulator to issue expected future base charging credits to utilities in advance, or else by leveraging a combination of base credit generation from vehicles already on the road and borrowing against future credit generation.

The results are shown for the average passenger, medium duty (class 3-6) and heavy duty (class 7&8) vehicle in Table 2, to the nearest hundred $. The precise values of potential rebates are sensitive to the details of assumptions about the NY-LCFS program design, rebate design, rates of EV deployment, and vehicular activity. As with other modeled results in this paper these should be treated as illustrative only.

Table 1. Potential vehicle purchase rebates for three options as an NY-LCFS program progresses

		2022	2026	2030
PV EV	**Last year**	$ 500	$ 1,300	$ 2,300
	Current year	$ 800	$ 1,800	$ 2,900
	Ten years	$ 2,700	$ 3,600	$ 4,300
MDV EV	**Last year**	$ 7,300	$ 22,600	$ 35,100
	Current year	$ 10,900	$ 27,000	$ 39,500
	Ten years	$ 28,200	$ 38,000	$ 41,000
HDV EV	**Last year**	$ 7,600	$ 32,600	$ 59,500
	Current year	$ 12,500	$ 39,900	$ 67,300
	Ten years	$ 67,500	$ 95,700	$ 108,000

For passenger vehicles, rebates could be made available with a value from $500 to as much as $4,000 per vehicle, depending on the year and the approach taken. For HDVs, the potential value is larger reflecting the higher rate of credit generation per vehicle, up to as much as $100,000 if ten years of value could be frontloaded.

The calculation clearly illustrates that the value of an NY-LCFS-funded vehicle purchase rebate would be sensitive to the way funding for the rebate is structured. For example, for passenger EVs the value per vehicle in 2022 under the ‘last year’ rebate is only a sixth of the expected value of the base charging credits that vehicle would generate over ten years, although the value calculated under the three systems converges as 2030 approaches for all vehicle types. The ‘ten year’ rebate structure may be more complex to implement, but would be a stronger driver of new sales. For all of the rebate designs considered, the potential rebate value increases over time – this reflects assumed increase in credit value over time, and for the ‘last year’ and ‘current year’ rebates reflects the fact that the available revenue increases as the fleet expands.

This pattern whereby the potential value of rebates increases as a program goes on contrasts with the expected reductions over time in the additional marginal cost of purchasing an electric vehicle. Figure 5 illustrates projections by the ICCT for the purchase price over time of ‘typical’ SUVs and cars, comparing conventional engines to battery electric and plug-in hybrid vehicles. The cost of battery electric vehicles is projected to come below the cost of conventional engine vehicles by the end of the decade.

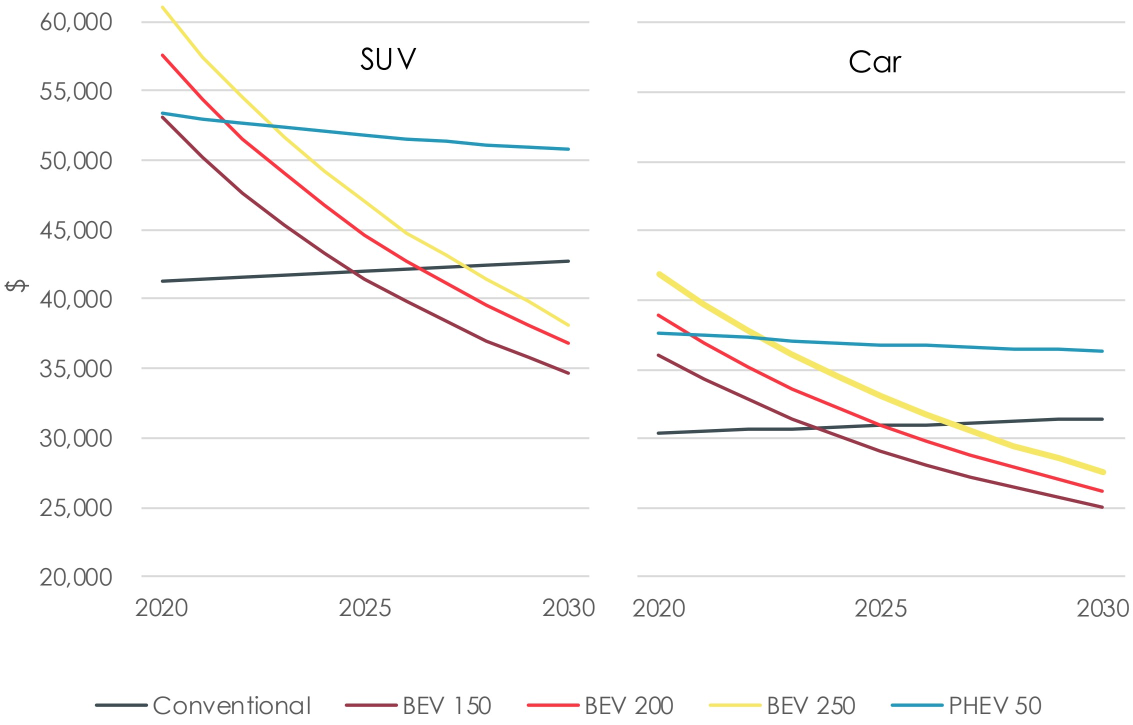

Figure 5. Initial purchase price of conventional vehicles and electric vehicles for cars and SUVs for 2020–2030

Source: ICCT estimates from Lutsey & Nicholas (2019)

It can be seen that as we reach the mid-2020s, the value available from an NY-LCFS funded rebate alone would be expected to be enough to cover most or all of the price gap between conventional and battery electric vehicles. This is consistent with the idea that a NY-LCFS could be a significant driver of EV sales this decade. As battery electric vehicles become less expensive than conventional vehicles, however, the question arises whether it would be necessary or appropriate to continue offering purchase rebates. One answer would be that as the program progresses a rebate scheme could be replaced with a scrappage scheme, encouraging drivers to take older more polluting vehicles permanently off the road. Another answer would be that as the program progresses revenue could be shifted away from universal purchase rebates and targeted to reduce electricity costs for charging, to continue to expand infrastructure, or to support further vehicle electrification in specific target markets, such as heavy duty vehicles in disadvantaged communities (this is discussed further in the section on air quality and health).

From the point of view of minimizing the costs of the transition to electric vehicles, a purchase rebate that ratchets up as the cost of the vehicles reduces has a certain appeal – maximizing the number of sales supported in later years as costs fall. On the other hand, from the point of view of maximizing the climate benefit of the program, there is a case to bring value forward with a view to accelerating market development. Finding the right balance in the disposition of NY-LCFS base-charging revenue is an important question to be carefully considered by the State Government and electric utilities generating base credits. Ideally, the legislative framework would provide some flexibility to the agency tasked with administering the residential rebate programs to adjust the program details to best deliver electric vehicle market development along with air quality and equity co-benefits.

3.2. Infrastructure credits

A second measure is being introduced to provide additional support for infrastructure for electric drive vehicles (hydrogen refueling stations and fast electric charging stations) – ‘capacity credits’. The idea of capacity credits is to reduce uncertainty about CA-LCFS credit revenue for infrastructure operators by allowing credits to be generated even when charging/refueling facilities are not being used (California Air Resources Board, 2018d). An operator investing in good faith in a hydrogen refueling station but suffering from a lack of customers (perhaps due to slow FCV sales) would thereby be given financial support from the award of CA-LCFS credits. This is the first time that credits will be awarded in a way that is disconnected from the supply of lower carbon intensity energy. The total award of such capacity credits is limited in any given year to 2.5% of deficits generated for each category (hydrogen and DC fast charging). This guarantees that at least 95% of credit generation in any given year will reflect delivered CO_2 emission reductions.

3.3. Medium and heavy-duty trucks and buses

The situation for operators of medium and heavy duty vehicles, especially for fleet operators, is potentially somewhat different to that for passenger vehicle owners because fleet operators are likely to be much more aware of total cost of ownership for their vehicles, making potential savings on energy costs an important part of purchase decision making. NY-LCFS credit value may therefore be expected to influence fleet decisions if returned to operators through reduced energy prices as well as if returned through rebate programs. Analysis of the total cost of ownership of electric medium- and heavy-duty vehicles in the case of California shows that CA-LCFS credit value is already a contributor to making expected total cost of ownership less for electric vehicles than for their ICE counterparts (ICF, 2019). Figure 6 shows total annual credit value generated by medium- and heavy-duty vehicles in Classes 3-6 and 7&8 respectively in the *balanced* scenario modeled below. Providing operational cost reductions on this scale to operators of electric medium- and heavy-duty vehicles can be expected to significantly accelerate sales.

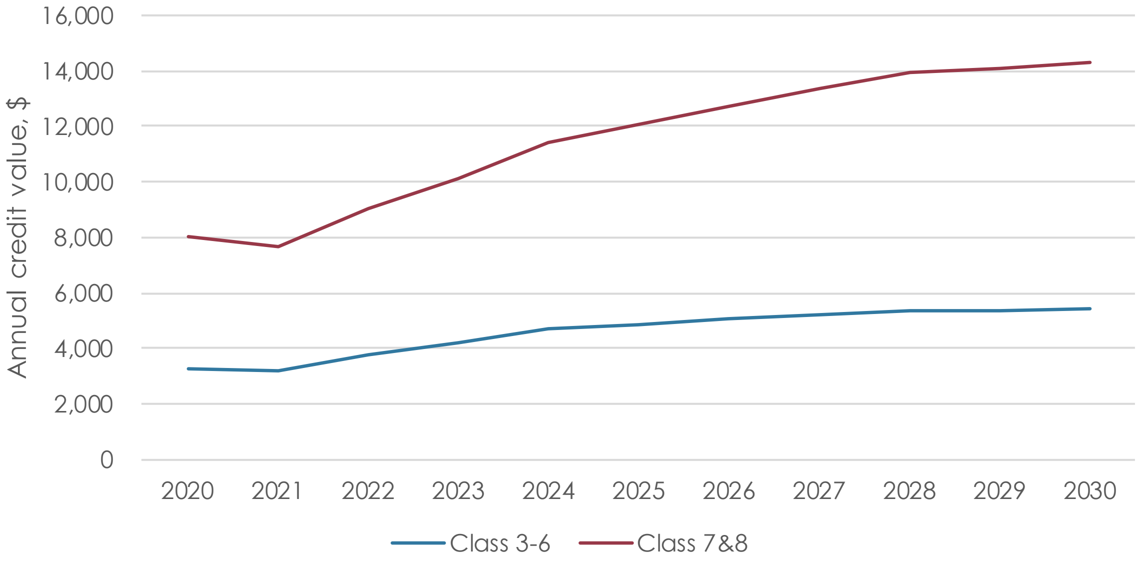

Figure 6. Annual credit value generated by for medium- and heavy-duty electric vehicles in the *balanced* scenario

For transit buses ICF (2019) anticipate that the purchase cost differential between diesel and electric buses will fall between 2019 and 2030 from about $275,000 to about $170,000. As with other medium- and heavy-duty EVs, the value of policies including the LCFS are shown to be vital in getting current total cost of ownership for electric buses below that for diesel buses. With similar annual diesel consumption to class 8 trucks (ICF, 2019, show about 7,500 gallons of diesel consumption annually for both transit buses and short haul class 8 trucks), transit buses are a market where the lifetime value of NY-LCFS credits could be a major driver of adoption.

4. Modeling a New York LCFS

The bills to introduce an NY-LCFS are simple – they create a requirement for a program to be developed and rolled out within 24 months and call upon regulators to look to other state programs as exemplars and as sources of carbon intensity data. In principle, New York regulators would have considerable flexibility to adjust the LCFS framework and some elements could be quite different than approaches in other states. Developing scenarios for compliance with a New York LCFS, as we do in this report, requires that some assumptions are made about the operation of a future New York LCFS.

The bills to introduce NY-LCFS allow drawing from the CA-LCFS experience. As such our modeling uses many details from the CA-LCFS. The results presented later reflect a framework largely based on the CA-LCFS, directly referencing carbon intensities calculated for the California standard. The CA-LCFS baseline against which carbon intensity reductions are measured is set based on analysis of fuel supplied in California in 2010. The bills to introduce an NY-LCFS do not specify a baseline year, but given that the proposed 20% carbon intensity reduction target for 2030 echoes the target set under CA-LCFS, we consider it reasonable to assume that New York will adopt a similar baseline. The calculation of the California baseline carbon intensities is based on extensive analysis, including a detailed characterisation of the carbon intensity of the oil supplied to California, and a characterisation of the carbon intensity of refining to produce California's specifications for gasoline and diesel fuels. New York is part of a different refining complex to California, with different feedstock oils, although refineries in both the Northeast and West (PADD 1 and PADD 5) have less access to Canadian oil sands crude and to fracked crude than other parts of the U.S.[14] Refineries serving California tend to be more complex with slightly lower energy efficiency than refineries serving New York (Elgowainy et al., 2014). It is likely that fossil fuel baseline carbon intensity values calculated specifically for New York would be slightly lower than the California values. For example, Cooney et al. (2017) found that the well-to-wheel carbon intensity of gasoline refined in California (PADD 5) in 2014 was 4.1 gCO_2e/MJ higher than the carbon intensity of gasoline refined in New York State (PADD 1). It is beyond the scope of this paper to propose alternative baseline values, but we note that reducing the fossil fuel baseline would have a small effect on the compliance modeling – less credits would be needed overall to meet targets, but less credits would be generated as the difference in carbon intensity between fossil and alternative fuels would be slightly smaller.

The NY-LCFS bills specify on-road transportation, and therefore we have not considered some categories of off-road credits that are included in CA-LCFS. This includes credits generated in California by electric light rail and forklifts, and credits offered for the use of alternative aviation fuels. Excluding aviation from crediting is unlikely to make a large difference to compliance in the 2030 time period. Only modest volumes of alternative aviation fuel are expected to be supplied by 2030, and alternative aviation fuel is chemically similar to renewable diesel, and if produced fuel is not supplied to aviation it can be supplied to diesel vehicles instead, with similar credit generation implications. Excluding electric passenger rail would reduce the credit supply but only by a modest amount – in California the number of credits from electricity for light rail and forklifts is currently about a third of the number of credits generated by biodiesel supply.

Several other credit generation options offered in California (refinery investment, refinery

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[14] https://stratasadvisors.com/Insights/101817-Key-Findings-By-PADD

renewable hydrogen, innovative crude production and low energy use refinery) are not considered in the main scenarios presented here. In the modeling we assume that all credits for electricity supply are awarded in the year of supply, i.e. the modeling does not consider the possibility that charging capacity credits could be front loaded. This, and other options to leverage credit value to drive investment, are discussed further below. We also exclude from consideration any incremental crude deficits from the modeling (deficits generated in CA-LCFS if the carbon intensity of crude used is higher than the baseline crude carbon intensity). Additional modeling assumptions required for cost and health analysis are discussed in the relevant sections below.

4.1. Compliance schedule

Modeling compliance against an NY-LCFS requires setting an assumed compliance trajectory for the standard – the bills specify only that 20% carbon intensity reduction should be achieved by 2030. For the modeling in this report we have assumed that 2022 is the first compliance year for the standard, and that a 5% carbon intensity reduction requirement is set for that year. The requirements then increase linearly to a 20% carbon intensity saving by 2030.

While 2022 is set as the first compliance year for the modeling, we have modeled the case that reporting is introduced earlier, and that credits are awarded for low carbon energy supplied in 2020 and 2021. No additional fossil fuel deficits are counted in these years. This results in a credit bank being developed before the standard comes into effect, and is intended to allow early adopters to accrue benefits from supplying lower carbon intensity fuels.

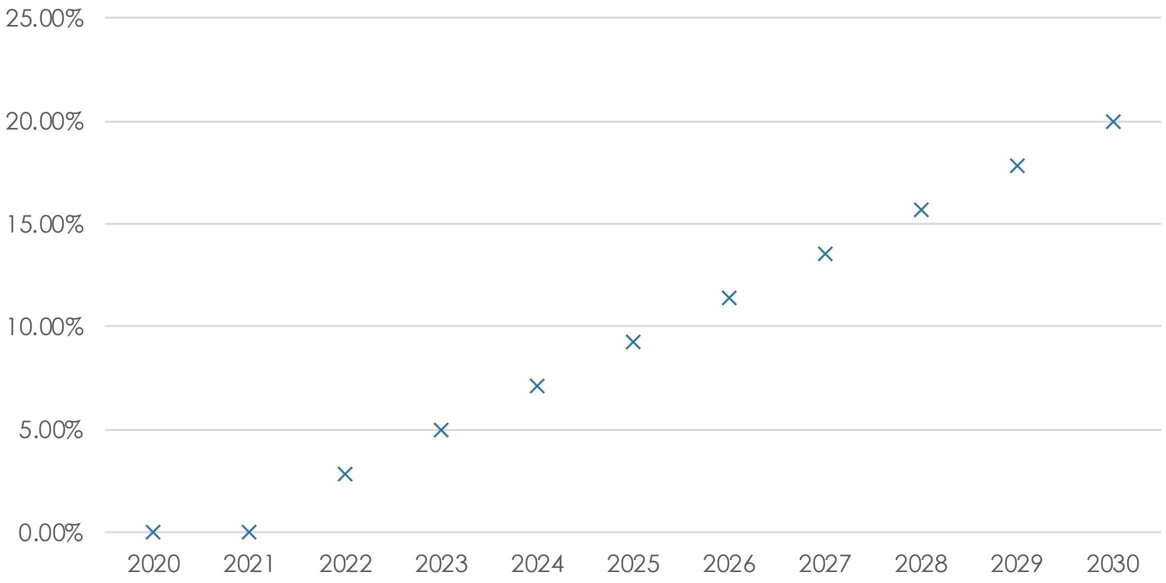

Figure 7. Modeled NY-LCFS compliance requirements

Allowing two years of pre-crediting will provide a credit buffer against any lower-than-expected credit generation as the NY-LCFS is introduced. A credit bank also allows non-linearity in credit generation growth (for ZEVs in particular) to be 'evened out' – the modeled scenarios see slight annual net deficits in most years which draw down the credit bank, with delivered carbon savings ‘catching up’ with the target again in 2030.

5. The credit supply model

This report presents results of scenario analysis to meet a target of 20% carbon intensity reductions by 2030 under a New York LCFS. The model used is built on the VISION model of vehicle stock turnover and energy use of the Argonne National Laboratory (Argonne National Laboratory, 2019b). The VISION model characterizes the U.S. national vehicle pool and associated energy consumption, divided up by vehicle type and fuel type. Vehicles are characterised by size and engine. Passenger vehicles are divided between cars and light trucks, and further divided by fuel used and drivetrain (including gasoline ICE, diesel ICE, hybrids, plug-in hybrids, flex fuel, natural gas vehicles, electric vehicles with three range categories, fuel cell vehicles). Larger vehicles are divided by weight class (medium duty trucks and comparable vehicles are grouped as Class 3-6, heavy duty trucks and comparable vehicles are grouped as Class 7&8), and similarly divided by fuel/energy type. For each vehicle type and each year modeled, VISION includes assumptions on average fuel efficiency, miles traveled, retirement rate[15], and annual sales (as a fraction of total sales of vehicles in that size class).

The credit supply model was initially developed (building on VISION 2014) by E4tech and the International Council on Clean Transportation (Malins et al., 2015) and has been further developed by (Malins, 2018b, 2019) (including updating to data from VISION 2017 for the latter study). For this project, the model has been further updated to use VISION 2019. As well as general updates to vehicle and energy use assumptions, the update to VISION 2019 adds explicit characterisation of medium- and heavy-duty electric vehicles[16], and adds the EV C category for light duty electric vehicles (EVs with a range of at least 300 miles).

In order to model an NY-LCFS the results from the national VISION model must be scaled to the New York market. Results are divided into a gasoline pool and diesel pool, and a scaling factor is applied to energy consumption in each of those pools to convert from national to state scale. Reported vehicle numbers are adjusted by the same factor according to fuel type (e.g. passenger EV numbers are scaled in line with the gasoline market, heavy duty EV numbers in line with the diesel market).

Assumptions about the availability of lower carbon intensity fuels are informed by consideration of the CA-LCFS and similar programs in other states, but we do not directly model allocations of resources between programs. Such modeling would in any case require assumptions to be made in detail about credit price hierarchies across different programs, and we do not believe that it is possible to make accurate predictions about such hierarchies before more details of a New York program have been confirmed. The underlying presumption is that the lowest carbon intensity fuels will be drawn preferentially to California or other West Coast markets, but that significant volumes of ‘low to medium’ carbon intensity fuels will still be available to New York State. For example, it is assumed that New York State would have access to much larger volumes of soy oil renewable diesel than of lower carbon intensity used cooking oil renewable diesel. In this report, the analytical scope is expanded from the earlier studies by directly considering financial and air quality implications of compliance, as explained below.

The modeling approach used for this study is similar to the approach documented for the previous work, and the same caveats apply. The model used is not economic and does not

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[15] The likelihood that vehicles are scrapped at a given age.

[16] Credit generation from medium- and heavy-duty EVs was included exogenously by Malins (2018b).

attempt to calculate least cost compliance pathways with an LCFS standard. The compliance scenarios are tuned so that compliance is indeed delivered, but the supply of credits is not directly responsive to illustrative credit prices used in the cost assessment. Rather, the model is used to generate scenarios for carbon intensity reductions that are considered plausible with reference to relevant literature and data, and to compare the carbon savings delivered in these scenarios to the carbon savings required to meet a set of LCFS targets. The results documented below should therefore not be treated as predictions for how an NY-LCFS *would* be met, but rather as illustrations of how it *could* be met. Similarly, when results are presented for costs and air quality implications, it should be understood that this are not intended as predictions but as illustrative scenarios. *If* an NY-LCFS were introduced as described, and *if* the standard was met in a way consistent with one of the scenarios presented, and *if* realized costs reflect the costs assumed, then the overall cost implications would be as described. In principle a more sophisticated iterative model could be used to develop predictions for what *will* happen, but the reality is that it is difficult to predict compliance choices, energy prices, regulatory design, interactions with other markets and many other important inputs. It would be an impressive model indeed that could accurately and reliably predict the pathway of transportation decarbonization for the next ten years, whether for a given state or for the country as a whole.

5.1. Credit generation options

5.1.i) Ethanol

Most gasoline in the United States is supplied with a 10% ethanol blend by volume (E10). Ethanol helps fuel suppliers meet obligations under the Renewable Fuel Standard, and acts as an octane enhancer. Ethanol can also be supplied at a 15% blend (E15) but the supply of E15 blends is limited by the EPA during the summer due to the potential for increased evaporative emissions. It is possible that legislative or executive action will be taken to encourage the supply of E15 between now and 2030[17], and action by the New York Department of Agriculture and Markets to enable E15 sales has been recently reported[18]. For the modeling in this paper we assume a standard E10 blend but note that moving to E15 would allow increased NY-LCFS credit generation with ethanol. Ethanol can also be supplied in higher blends up to 85% (E85) to vehicles identified as ‘flex fuel’. While flex fuel vehicles are relatively common, they tend to be filled with regular gasoline (E10 blend) rather than taking advantage of specialized E85 fueling opportunities. VISION assumes that flex fuel vehicles currently use E85 for only about 2% of miles traveled. For the modeling in this report we assume that this does not increase.

The contribution of ethanol use to NY-LCFS compliance would be determined not only by the volume supplied but also by the reportable carbon intensity. Under the CA-LCFS, reported carbon intensity for corn ethanol has declined since the program started, reflecting a combination of improved production efficiency, more accurate reporting by producers who were already more efficient than average and preferential use of lower carbon intensity ethanol in state. We assume that through the 2020s the average carbon intensity of corn

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[17] E.g. https://fortune.com/2018/10/11/ethanol-gas-e15-trump/

[18] https://biofuels-news.com/news/new-york-state-approves-sale-of-cleaner-burning-ethanol-blended-e15-fuel/

ethanol supplied under an NY-LCFS would improve by 12 gCO_2e/MJ given the LCFS value signal.

5.1.ii) Biodiesel

Similar to ethanol, biodiesel can be supplied blended into diesel fuel. For blends of up to 5% this does not require additional labeling[19]. Higher blends up to 20% (B20) are often sold for used in unmodified diesel engines, and blends up to 100% biodiesel (B100) are be available from some fuel retailers. Most U.S. biodiesel is produced from soy oil and counts as an 'advanced' biofuel under the RFS, and therefore receives a more valuable credit under RFS than corn ethanol does.

We were not able to find documentation of the current typical biodiesel blend level in New York State, and therefore assume that it is in line with the national average. In the *balanced* scenario, biodiesel blending increases slightly to reach 7% on average for NY diesel by 2030.

As with ethanol, additional NY-LCFS credits could be generated by sourcing lower carbon intensity biodiesel, either by improving the efficiency of soy biodiesel production or by switching to feedstocks with lower reportable carbon intensity, such as used cooking oil, distillers' corn oil or animal fats. The modeling assumes that the value proposition for the lowest carbon intensity biodiesel will be stronger under the CA-LCFS than an NY-LCFS, and therefore that most of the lowest carbon intensity biodiesel from by-products and waste materials will continue to preferentially head west. In the *balanced* scenario, it is assumed that the average carbon intensity of biodiesel supplied reduces by 6 gCO_2e/MJ by 2030.

5.1.iii) Renewable diesel

Renewable diesel, also referred to as hydrotreated vegetable oil (HVO) is produced from the same resources as biodiesel (vegetable oils and animal fats), but is more intensively processed in order to produce a 'drop-in' alternative diesel fuel with chemical properties extremely similar to fossil diesel fuel. Given the chemical similarities, renewable diesel can be supplied in any blend with fossil diesel without creating problems for existing engines. Renewable diesel is not completely chemically identical to the fossil alternative though, and generally combusts more cleanly, resulting in reduced NOx and SOx emissions[20] (California Air Resources Board, 2018b). Like biodiesel, most renewable diesel can earn advanced RFS credits.

U.S. renewable diesel production capacity had reached 240 million gallons by 2017 (Carter, 2018), and was complemented by a similar volume of imports. Renewable diesel production capacity is currently growing rapidly, with major investments in the U.S. and elsewhere. A market analysis by "Emerging Markets Online" reportedly predicted fourfold expansion of global capacity by 2030[21], and just two projects large declared in the U.S. are set to add a billion gallons of capacity in the near future[22]. Illustrative compliance scenarios for the CA-LCFS

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[19] https://afdc.energy.gov/fuels/biodiesel_blends.html

[20] Oxides of nitrogen and sulphur respectively.

[21] https://www.biofuelsdigest.com/bdigest/2019/04/22/renewable-diesel-is-a-game-changer-for-sustainable-aviation-and-low-carbon-fuel-markets-in-the-u-s-canada-europe-and-southeast-asia/

[22] http://www.biodieselmagazine.com/articles/2516631/where-will-all-the-feedstock-come-from

include between 700 million and 1.5 billion gallons of consumption by 2030 (California Air Resources Board, 2018c). Total U.S. renewable diesel demand in the coming decade is likely to be sensitive to the overall level of ambition set in state programs such as LCFSs and on the rate of deployment of the electric vehicle fleet. If less LCFS tickets are generated by electric vehicles than expected, then competition between LCFSs could lead to a tight market for renewable diesel. For more moderate scenarios, however, it seems reasonable to assume that something on the order of hundreds of millions of gallons could be available to New York with a clear credit price signal. In the *balanced* scenario, we model 190 million gallons of renewable diesel consumption, using mostly crop-based feedstocks (soy and canola oils). If the NY-LCFS credit price rose above that under the CA-LCFS, then lower carbon intensity waste and residual feedstocks could play a greater role.

5.1.iv) Renewable natural gas

Natural gas has a lower carbon intensity than diesel, and therefore supplying fossil natural gas for vehicles can generate LCFS credits. A much greater carbon benefit can be delivered, however, by the use of renewable natural gas produced through anaerobic digestion of biomass. In some cases, such as the capture of dairy gas that would otherwise be emitted to the atmosphere contributing to global warming, the carbon intensity value allocated under the CA-LCFS is actually negative. This represents the dual benefit of avoiding the combustion of fossil carbon and reducing emissions of methane.

New York State currently, however, reports very little supply of natural gas for road transport (U.S. EIA, 2020) – much less as a fraction of transportation energy than in California. A significant expansion of the natural gas vehicle fleet would be required for credits from renewable natural gas to become a significant contributor to meeting NY-LCFS targets. In the *balanced* scenario sales of natural gas vehicles increase to 6% and 12% by 2030 for Class 3-6 and Class 7&8 vehicles respectively. The opportunity to generate credits from renewable natural gas use could be expanded by considering the use of renewable natural gas for process energy, for instance for generating electricity for battery electric vehicles or as fuel for petroleum or ethanol refineries, but these options are not modeled here.

New York has potential to produce significant quantities of renewable natural gas. Analysis by Energy Vision (Energy Vision, 2020) identifies 36 million diesel gallons equivalent (DGE) of existing RNG production in New York from dairy manure, food waste, wastewater management, and landfill gas. The total technical potential is over 200 million DGE, enough to meet all of current transportation demand for gas, though delivering this would require significant investment in new gas capture projects only some of which are likely to be economically viable.

While there is significant local potential for RNG production, if New York adopts the same accounting rules as used under the CA-LCFS there would be no requirement that RNG credited under an NY-LCFS should be locally produced. The CA-LCFS allows mass balance accounting across the national natural gas pipeline network, so that natural gas consumed in California can be treated as renewable provided that an equivalent amount of RNG is injected to the gas grid somewhere in the country. This accounting systems allows all natural gas supplied for transport to be reported as renewable under the CA-LCFS (cf. Malins, 2018b). According to Argonne National Laboratory (2019a), the U.S. has about 370 million DGE of annual RNG capacity. About 170 million DGE are required to report all of the natural gas supplied under CA-LCFS as renewable, and this could increase to 320 million DGE by 2030 (California Air

Resources Board, 2018c). For 2019, this leaves 200 million DGE of renewable characteristics available to be allocated to other consumers, including under NY-LCFS. A further 100 million DGE of capacity is identified as already under construction, suggesting that national capacity should grow faster than demand under the CA-LCFS. The additional value signal from new LCFS programs in New York State and potentially elsewhere should accelerate deployment of gas capture technologies, and it may be possible to implement rules that would provide preferential support to the development of renewable natural gas supplies from within New York State.

If the NY-LCFS offers a significant value proposition then it would seem reasonable to expect that, as under the CA-LCFS, most or all of the natural gas supplied for transportation under an NY-LCFS will be reported as renewable. This is based on the expectation that national capacity should be adequate to cover demand from both jurisdictions, and probably also meet demand from smaller programs in Oregon etc. and from other consumers keen to demonstrate the use of climate friendly fuels. For a weaker value proposition, or for the case that there is an increase in competition for RNG from other states and/or programs, then only a fraction of natural gas supplied may be reported as renewable.

5.1.v) Passenger vehicle electrification

New York State has ambitious goals in place for expansion of the ZEV fleet, and significant expansion is to be expected even in the absence of an NY-LCFS. New York follows the California ZEV mandate, and New York State has a target to have two million electric vehicles on the road by 2030.[23] A NY-LCFS with accompanying EV purchase rebates and charging infrastructure credits could contribute to achieving those targets.

In the modeling, it is assumed that electric vehicle sales in the baseline follow the reference case outlined by TCI (Transportation & Climate Initiative, 2019), as shown in Figure 8. For the two scenarios modeled in this report, it is assumed that the revenue from NY-LCFS credits drives increases in electric vehicle sales fractions. These sales fraction increases are scenarios, not predictions. The actual impact of an NY-LCFS on ZEV sales will be sensitive to implementation decisions (such as the use and structure of purchase price rebates) and to other aspects of ZEV support in New York State. The modeled sales fractions for the *balanced* and *high ZEV* scenarios are based on the sales fractions identified by TCI as necessary to comply with a 22% or 25% emission reduction cap for transportation respectively (Figure 9).

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[23] https://www.nyserda.ny.gov/About/Newsroom/2019-Announcements/2019-04-23-Governor-Cuomo-Announces-Record-Number-of-Electric-Vehicles

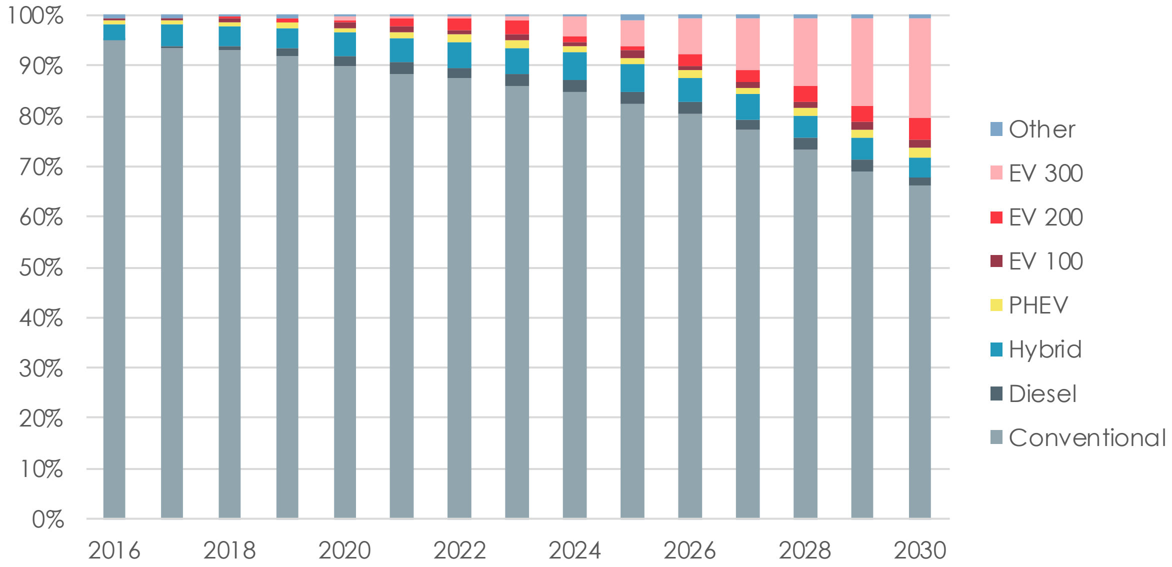

Figure 8. **Passenger vehicles sales fractions in the baseline**

Source: Transportation & Climate Initiative (2019)

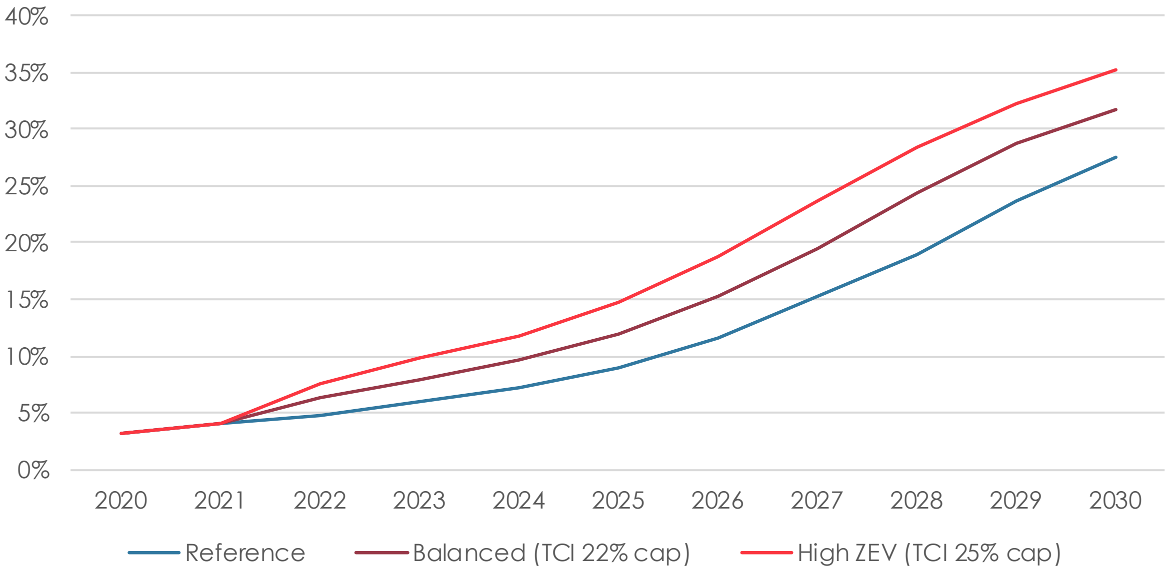

Figure 9. **Passenger electric vehicle sales fractions for the scenarios considered**

Source: Transportation & Climate Initiative (2019)

5.1.vi) Fuel cell vehicles

Hydrogen fuel cell vehicles and hydrogen fueling infrastructure are another potential beneficiary of LCFS credit revenue, but fuel cell passenger vehicle sales are not explicitly identified in the TCI modeling. For both scenarios, we assume passenger FCV sales are 0.1% of new car sales in 2020, increasing to 2.3% by 2030.

5.1.vii) Medium- and heavy-duty vehicle electrification

It is not only in the passenger fleet that electric drive vehicle use is increasing – electrification is also progressing for medium- and heavy-duty vehicles, including buses and trucks. For example, New York State has, since 2013, been running a voucher program (New York Truck Voucher Incentive Program, NYTVIP) offering point of sale discounts to reduce the cost of battery electric bus (BEB) technologies (NYSERDA, 2020). Under the first round of the program, 65 battery electric bus purchases were supported, at an average voucher value of $90,000. A new round of vouchers, supported by funds from the Volkswagen settlement and the Congestion Mitigation and Air Quality (CMAQ) Improvement Program, will distribute $35 million with awards of up to $385,000 for the heaviest class of battery electric and fuel cell vehicles, with the grants tied to a scrappage requirement for older more polluting vehicles.

In the modeling, baseline sales rates for medium- and heavy-duty electric vehicles and fuel cell vehicles is based on default average national sales rates set in VISION 2019. As noted above, the value proposition from NY-LCFS should significantly improve the economics of electric medium- and heavy-duty vehicles as compared to conventional vehicles. In the *balanced* scenario, we assume a fivefold increase in sales rates for these vehicles above the baseline sales rates. ZEVs account for 8% of class 3-6 and 3% of class 7-8 truck sales in 2030. In the *high ZEV* scenario, a tenfold increase is assumed (i.e. the sales rates are double those in the *balanced* scenario). In practice, delivering such increased rates of medium/heavy duty electric vehicle deployment would be dependent on effectively leveraging the associated NY-LCFS credit revenue to support purchase decisions, for instance through outreach and information sharing about the operational cost savings achievable through the lifetime of a vehicle or the offer of rebates analogous to those discussed for passenger vehicles.

5.1.viii) Cellulosic biofuels

When the CA-LCFS entered implementation, there was a widely held expectation that cellulosic biofuel production would make a major contribution to compliance, driven by LCFS itself, the rapidly increasing targets under the RFS and the availability of a range of financial support from the Department of Energy and Department of Agriculture. Fast forwards ten years and the latest illustrative compliance scenarios for CA-LCFS consider no more than 150 million gallons of cellulosic ethanol by 2030, and do not consider cellulosic drop-in fuels at all. The cellulosic biofuel industry has struggled to raise investment, and such facilities as have entered operation have struggled to succeed (cf. Malins, 2018a; Miller et al., 2013). Early studies of the costs of cellulosic biofuel production may have tended to understate the costs of both feedstock and capital (Witcover & Williams, 2020). Most commentators do not currently anticipate a sudden rapid expansion of the industry.

This study follows the cellulosic biofuel modeling assumptions detailed in Malins (2019). A combination of assumed slow production capacity expansion and assuming that other markets such as CA-LCFS may be more attractive for cellulosic biofuel supply for some years to come results in very modest volumes being considered in the modeling. Cellulosic biofuels are therefore not a major contributor to the modeled compliance scenarios.

5.1.ix) Electrofuels

Electrofuels, also referred to a power-to-liquids fuels, are hydrocarbons synthesized from electrolytic hydrogen. Where the hydrogen is produced with renewable electricity, these fuels can have low carbon intensity. While such fuels may become an important contributor to transport decarbonization in the longer term, in the coming decade it is considered unlikely that large enough volumes would be produced to make a significant contribution to NY-LCFS compliance. They are therefore not considered in the scenarios presented here.

5.1.x) Other crediting options under the CA-LCFS

The CA-LCFS allows for crediting for a number of other carbon emissions reduction strategies outside the on-road transportation sector. These include:

1. Refinery CCS
2. Investments in reduced refinery CO_2 emissions
3. Use of renewable hydrogen at refineries
4. Credits for 'innovative' lower carbon intensity crude oil extraction (e.g. solar heat for thermally enhanced oil extraction)
5. Credits from electric rail and forklifts
6. Credits for lower carbon intensity aviation fuel
7. Charger installation credits
8. Hydrogen fueling station capacity credits

These credit generation options are not included in the main scenario analysis in this report. Together they make a significant contribution to credit generation in illustrative compliance scenarios for CA-LCFS (e.g. 12% of total credit generation 2020-2030 in the low demand *high ZEV* scenario shown in Figure 3).

Adding additional credit generation opportunities to the system through options such as these would aid compliance and could allow slight reductions in compliance costs and credit prices. To illustrate this, a sensitivity case is included in which credits are awarded for electricity consumption on the New York subway, allowing reductions in consumption of low carbon liquid and gaseous fuels while still delivering compliance with the modeled NY-LCFS targets. For this sensitivity it is assumed that electricity consumption by the subway is steady at about 1.8 billion kilowatt hours (www.nycsubway.org, 2012), and that 83%[24] of this electricity is consumed for motive power. Following the CA-LCFS approach, this electricity consumption is credited based on an EER of 1 (California uses higher EERs for rail expansion after 2010 only).

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[24] Based on data for the London Underground in the absence of New York specific data, (TfL, 2014).

5.2. Analysis of costs implications

For this study, the credit supply model has been extended with a view to providing an indication of some of the potential financial implications of the implementation of an NY-LCFS. This analysis requires simplifications and does not constitute a comprehensive cost-benefit analysis of an LCFS program but does provide an indication of the scale of some of the major financial flows and monetized benefits that might result. VISION includes expected prices for the various energy types based on the Annual Energy Outlook (AEO) (U.S. EIA, 2018), and these are used as the basis of the cost analysis.

A baseline for comparison is constructed assuming that volumes and carbon intensities of ethanol and biodiesel are more or less constant (supported by the RFS), and that passenger electric vehicle use grows at a pace consistent with the reference case for electric vehicle sales in the Northeast detailed by Transportation & Climate Initiative (2019). Medium- and heavy-duty electric vehicle sales shares follow VISION defaults. Natural gas vehicle sales fractions fall a little by 2030 compared to the 2020 assumed rates, and it is assumed that without the driver of an LCFS all gas supplied is fossil natural gas. There is no consumption of cellulosic biofuels or renewable diesel in this baseline. Setting a baseline allows the assessment to distinguish between the marginal changes to the transportation energy supply assumed to be driven by the standard, and other changes that are a result of 'business as usual' market developments or that are driven by other programs such as the ZEV mandate. Of course, evaluating potential costs and benefits against a baseline means that the results presented are sensitive to the construction of that baseline. We emphasize again that the results presented here should be treated as illustrative only.

Having constructed a baseline scenario for comparison, costs and benefits in the LCFS scenarios are identified based on a simple NY-LCFS credit price model, and on a number of simplifying assumptions. A simple dynamic model for NY-LCFS credit prices has been implemented in which credit prices start at 50 $/tCO_2e$ in the assumed reporting-only years, and increase if the credit bank is drawn down and annual credit requirements are large compared to credit generation. For the scenarios considered, this results in assumed credit prices in the 50-150 $/tCO_2e$ range, with slightly higher prices in the *high ZEV* scenario due to more draw down of the credit bank. In reality, credit prices will be determined by a complex interplay of fuel availability, demand from other jurisdictions, rate of technology deployment and market confidence. The prices used in the modeling here should not be understood in any sense as predictions, but simply as a mechanism to allow cost scenarios to be constructed.

It is assumed that the adoption of an NY-LCFS does not result in fuel suppliers having to pay higher prices for existing sources of ethanol and biodiesel for blending. The additional value available from LCFS credits on existing biofuel supplies would not accrue directly to ethanol producers, rather those credits would be earned by blenders and would be offset against deficit generation. Fuels suppliers would not be forced to pass this value along the supply chain unless specifically seeking out supplies of fuel with lower-than-typical carbon intensity. This assumes that the potential supply of corn ethanol at average carbon intensities is large compared to the demand from New York State, and therefore ethanol producers would have little scope in a competitive market to increase sales prices for those average fuels to New York fuel suppliers.

Per gallon biofuel prices would only be increased *for lower carbon intensity fuels*, for which fuel suppliers in New York would compete with other LCFS markets. It is assumed in the assessment that the additional marginal cost of lower carbon intensity fuels is directly proportional to the reduction in carbon intensity of those fuels against the assumed pre-LCFS average, so that there is an additional cost only for additional carbon savings. This means, for example, that if a scenario was modeled neither the volume nor carbon intensity of biodiesel use differed from the baseline then none of the assumed cost associated with biodiesel use would be attributed to LCFS.

The case for renewable diesel is different. As it is assumed that NY-LCFS would be the primary driver of renewable diesel consumption. VISION 2019 does not include any projection of renewable diesel costs, and therefore prices are calculated based on AEO biodiesel price projections, assuming an 85 cent per gallon renewable diesel premium. These price assumptions are broadly consistent with published estimates of the cost of renewable diesel production. The case that strong demand for renewable diesel could cause prices to rise well above production price is not accommodated in the modeling. As with ethanol and biodiesel, an additional marginal price contribution proportional to the credit price and carbon intensity reduction is assumed for lower carbon renewable diesel.

Electricity prices are taken from AEO as documented in VISION 2019, and it is assumed that electricity prices are unaffected by the NY-LCFS. Whereas for liquid fuels it is assumed that fuel consumers may not bear the full implied cost of carbon credits (as fuel blenders are expected to earn credits and offset them against deficits), it is assumed that all credits from electricity supply are sold at the credit price to liquid fuel suppliers. There is therefore a direct transfer assumed from liquid fuel consumers to electric vehicle owners/operators. Credits from passenger ZEVs are assumed to be supported by gasoline sales, credits from medium- and heavy-duty ZEVs are assumed to be supported by diesel sales.

Natural gas prices are taken from AEO. The price of renewable natural gas is assumed to be the natural gas price, again plus the value of the marginal carbon intensity reduction. As with electricity, it is assumed that credits from natural gas supply are all sold at the credit price to liquid fuel suppliers to help meet their obligations, creating a transfer from liquid fuel consumers to natural gas vehicle owners/operators. Natural gas credits are assumed to be supported by diesel sales.

In the cost analysis, it is assumed that costs of shifting to diesel substitute fuels, natural gas vehicles and of medium- and heavy-duty electrification are borne by diesel consumers, and that costs of shifting to gasoline substitute fuels and passenger vehicle electrification are borne by gasoline consumers. In practice, the costs of compliance may be spread somewhat across the diesel and gasoline pools, so that diesel consumers may end up supporting passenger EVs and gasoline consumers may end up supporting renewable diesel supply. We assume full pass through of LCFS costs from obligated parties to fuel consumers.

There are also cost implications associated with purchasing new electric vehicles instead of ICEs. Figure 5 in the section discussing rebates showed estimates by the ICCT of the evolution of the typical purchase price of comparable cars and SUVs in the period 2020 to 2030. The initial purchase cost of battery electric vehicles in all range categories for both cars and SUVs are predicted to achieve parity with ICE vehicle costs at some point in the mid-2020s, and that after this point BEVs are predicted to have lower initial purchase prices than ICE vehicles.

An indicative analysis of the impact on total cost of new passenger vehicle sales is undertaken based on these cost differentials. Costs for BEV 150 are treated as representative of the EV A category in VISION, costs for BEV 200 representative of the EV B category and BEV 250 representative of the EV C category. PHEV 50 costs are used for all PHEVS. For heavy duty vehicles additional purchase costs for both natural gas and electric vehicles are estimated based on the prices detailed by ICF (2019), reaggregating where necessary into the class groupings used by VISION (class 3-6 and class 7&8, see Figure 10).

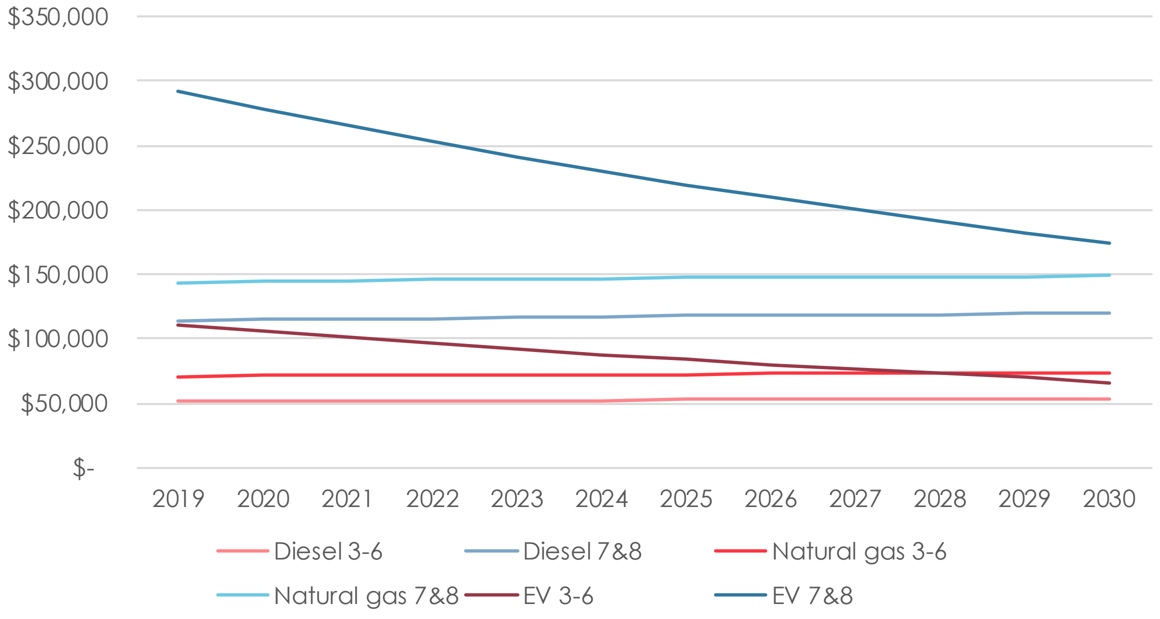

Figure 10. Assumed typical medium- and heavy-duty vehicle purchase cost, 2019 to 2030

Source: ICF (2019)

6. Credit generation scenarios

Using the model as described above, we have developed two main scenarios to illustrate pathways available for New York State to deliver compliance with a low carbon fuel standard with a 20% transportation carbon intensity reduction requirement for 2030. Credit banking is allowed, as in the CA-LCFS. The first of these, referred to henceforth as the *balanced* scenario, assumes a mix of compliance options being used including increased volumes and reduced carbon intensities for liquid and gaseous alternative fuels, and that ZEV deployment runs slightly ahead of the baseline rate taken from Transportation & Climate Initiative (2019), including some deployment of medium and heavy duty electric vehicles. The second scenario, referred to henceforth as the *high ZEV* scenario, assumes that ZEV deployment is slightly more aggressive in both the passenger and medium/heavy duty fleet, allowing for reduced credit generation from liquid and gaseous fuel supply options. A third sensitivity scenario is also presented, exploring the implications of allowing the New York City subway to generate NY-LCFS credits and thereby reduce the need for credits from other pathways.

6.1. Balanced scenario

In the *balanced* scenario, total carbon intensity reductions delivered reach 19.3% by 2030 (Figure 11). Banked credits are used to meet the remaining 0.7% requirement in 2030.

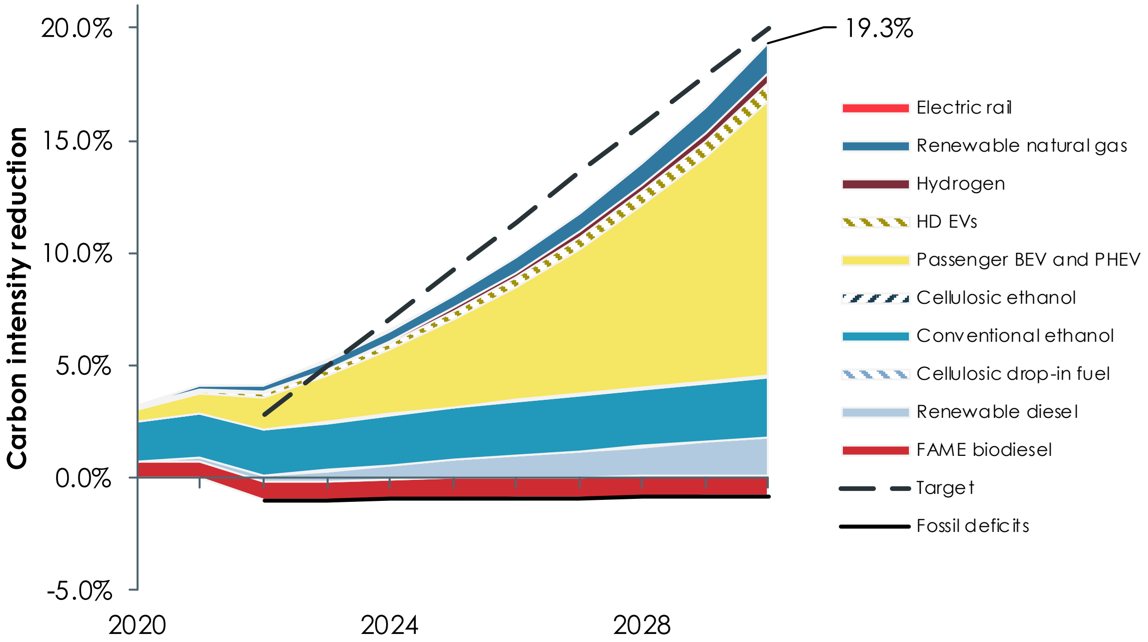

Figure 11. Carbon saving contributions in the *balanced* scenario

Passenger electric vehicles make the largest contribution, and there are significant additional contributions from conventional ethanol, renewable natural gas, renewable diesel, biodiesel and medium/heavy duty electrification. Passenger EV sales rates are consistent with the scenario for a 22% CO_2 emissions cap reduction by 2032 described in Transportation & Climate Initiative (2019). This results in a passenger ZEV population of 1.7 million vehicles in 2030, 15% higher than in the baseline. The MD/HD EV fleet grows to 17 thousand vehicles. Average biodiesel blend rate is assumed to increase to 7% (B7), and renewable diesel blending increases rapidly to 14% by 2030. It is assumed that partial deployment of E15 ethanol increases the average ethanol content in gasoline to 12.5% on average. Even so, total ethanol consumption fall slightly as gasoline consumption is reduced by increased efficiency and by EV deployment. Expansion of the medium- and heavy-duty natural gas vehicle fleet to 12,000 vehicles allows renewable natural gas consumption to deliver significant credit generation.

As seen in Figure 12, credits awarded in the pre-compliance years (2020 and 2021) allow a significant credit bank to be built up, which is slowly drawn down as 2030 approaches.

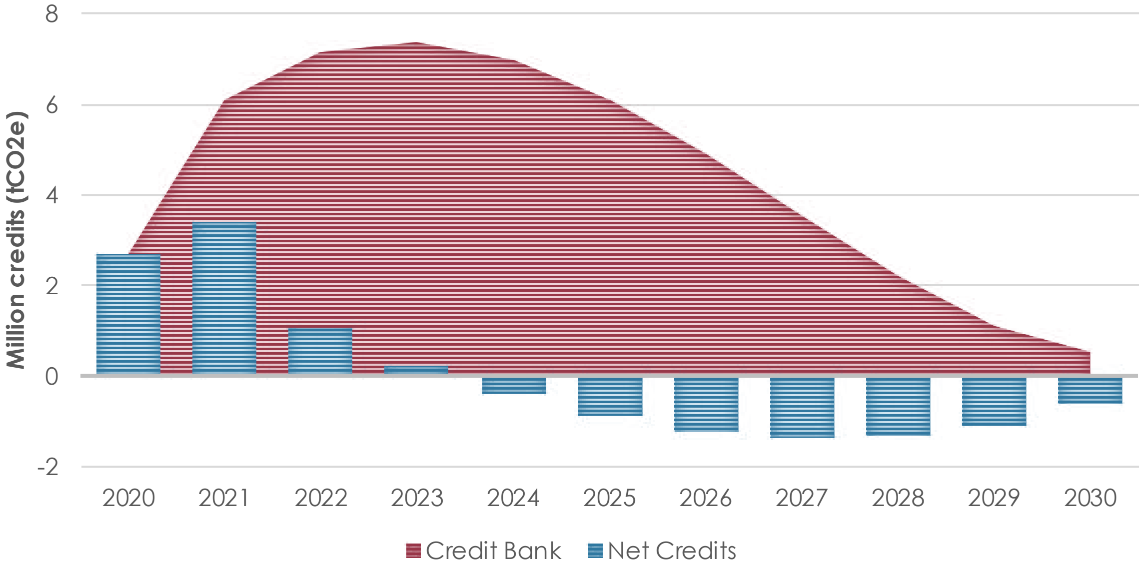

Figure 12. Credit bank development in the *balanced* scenario

The final supply of alternative transportation energy is shown in Figure 13. Increases in lower carbon energy supply are delivered through electricity and renewable diesel – additional credits from other fuels are achieved primarily through reductions in carbon intensity. The use of electricity for plug-in electric vehicles delivers a large contribution to carbon intensity reductions despite the relatively modest absolute amount of energy supplied because of the low carbon intensity assumed for the electricity, and because of the higher efficiency of electric drive vehicles (credit generation is calculated using CARB's energy efficiency ratios).

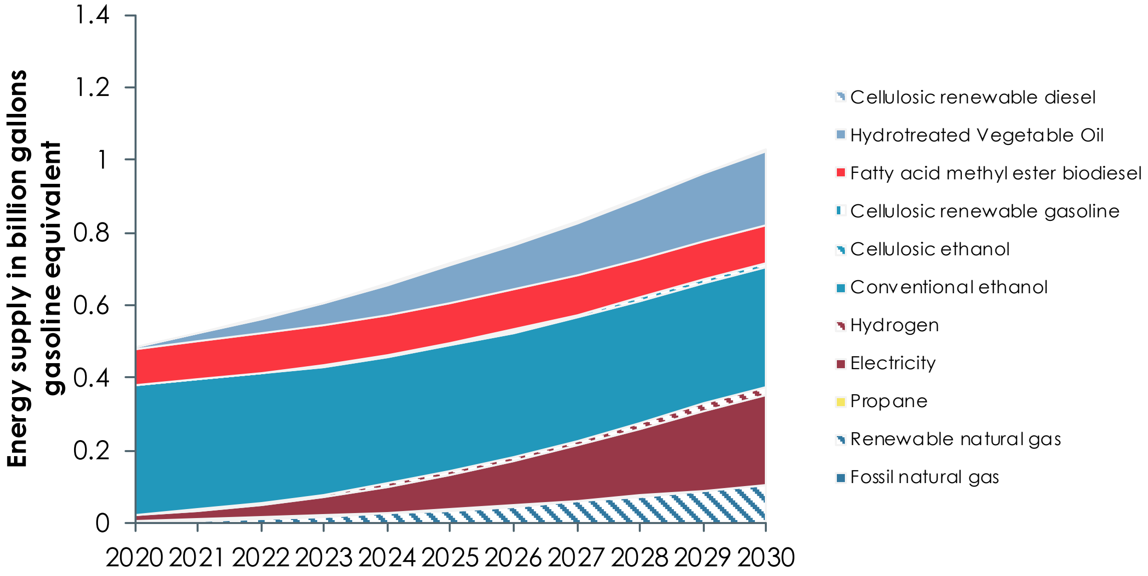

Figure 13. Supply of alternative transportation energy in the *balanced* scenario

6.2. *High ZEV* scenario

As in the *balanced* scenario, passenger electric vehicles produce the largest carbon savings in the *high ZEV* scenario, but with increased sales they have an even larger role, delivering over 50% of cumulative credit generation over the course of the program (Figure 14).

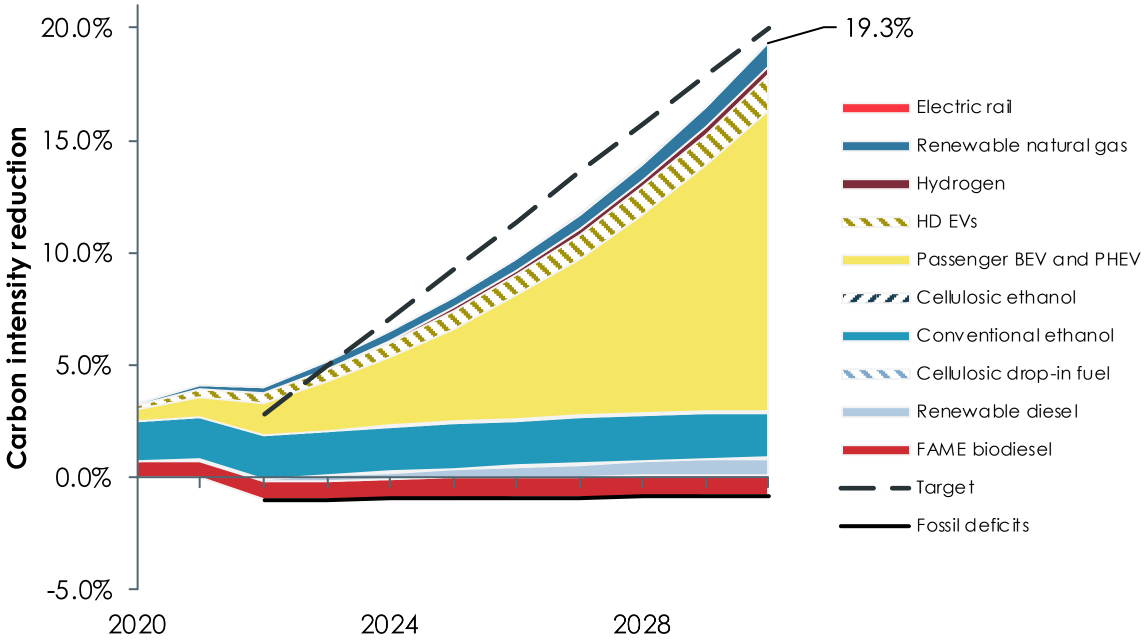

Figure 14. Carbon saving contributions in the *high ZEV* scenario

In this scenario, ZEVs sales rates are based on the case of a 25% GHG emissions cap for 2032 described in Transportation & Climate Initiative (2019). The contribution from medium- and heavy-duty ZEVs is increased but is still much less than that from passenger ZEVs. The standard ethanol blend remains at E10, but biodiesel blending increases to B7 as in the *balanced* scenario while renewable diesel use grows to 6% of liquid diesel fuel by volume.

Evolution of the credit bank is similar to the *balanced* scenario (Figure 15). With a faster roll out of more efficient electric vehicles, less overall alternative transportation energy supply is required to meet the standard (Figure 16).

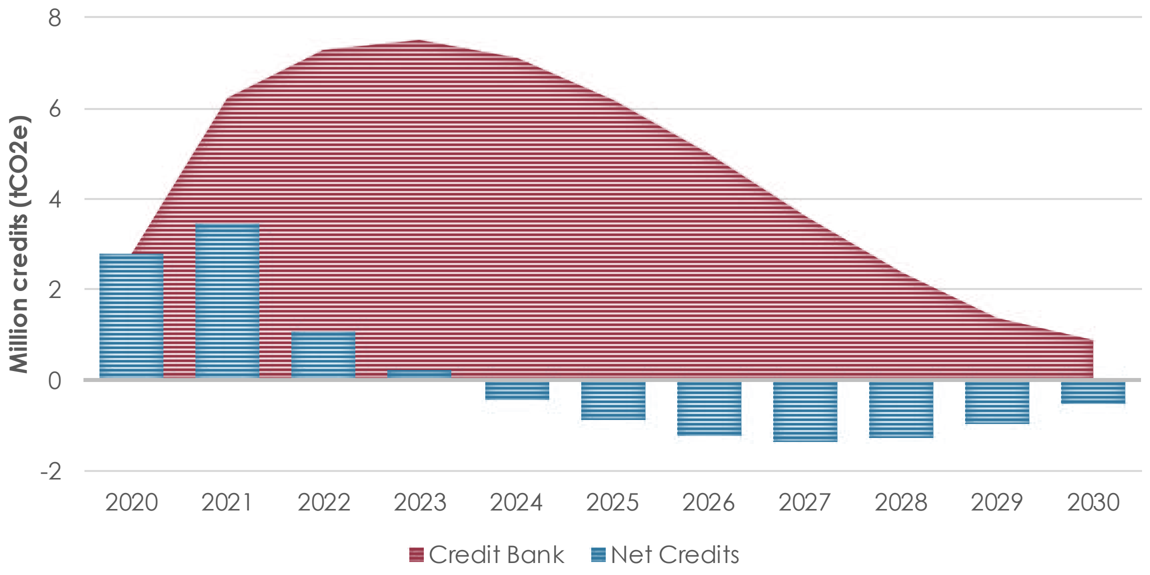

Figure 15. Credit bank development in the *high ZEV* scenario

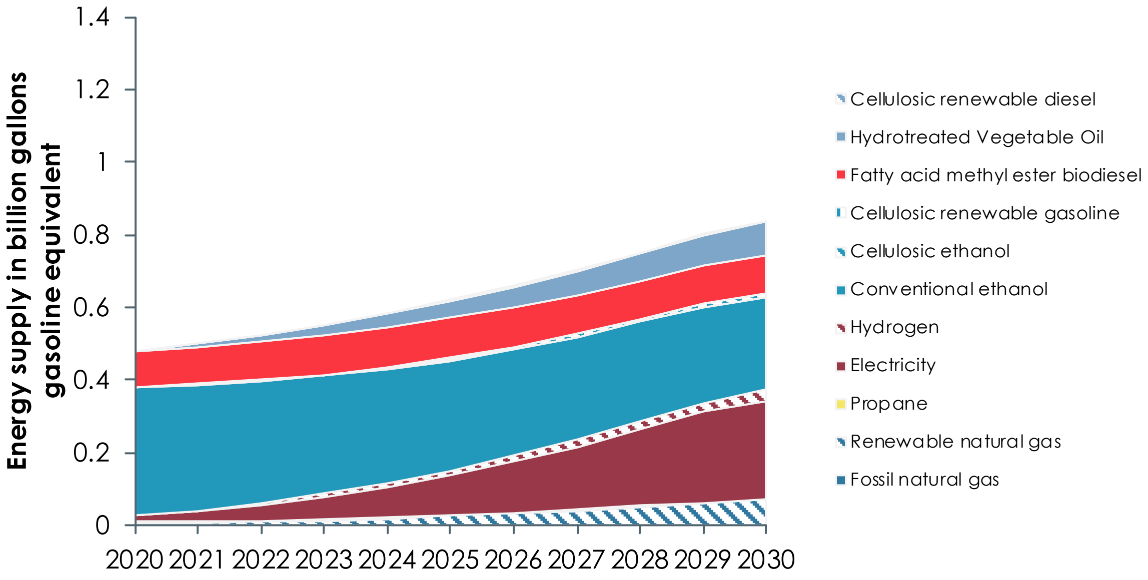

Figure 16. Supply of alternative transportation energy in the *high ZEV* scenario

6.3. Sensitivity: crediting for NYC subway

In this sensitivity case, crediting of electricity for subway trains is added. This results in 400-450 thousand additional NY-LCFS credits being generated in each year, 4.7 million additional credits by 2030. The availability of these credits allows the use of other compliance options to be reduced while still meeting the 2030 target – we have considered the case that the supply of liquid and gaseous alternative fuels is reduced compared to the *balanced* case. As shown in Figure 17, introducing these additional credits without adjusting the compliance trajectory allows more credits to be generated early in the program, so that given the credit bank an 18.5% carbon intensity reduction in 2030 allows compliance to be delivered. The supply of biodiesel, renewable diesel and renewable natural gas are all reduced compared to the *balanced* scenario (blends of 5% and 6% respectively for the diesel alternatives, and only eight thousand natural gas medium- and heavy-duty vehicles).

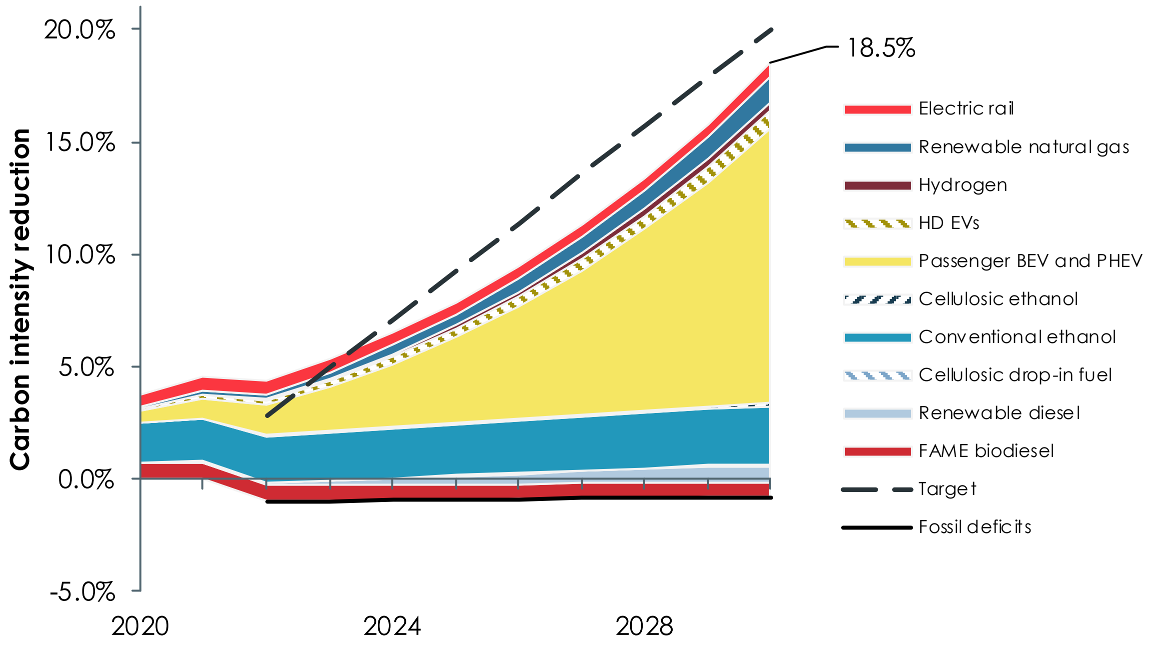

Figure 17. Carbon saving contributions in the sensitivity case

6.4. Comparison of scenarios

Figure 18 provides a comparison of the sources of cumulative credit generation across the three scenarios. As can be seen, there are only modest differences between the credit generation options across the cases.

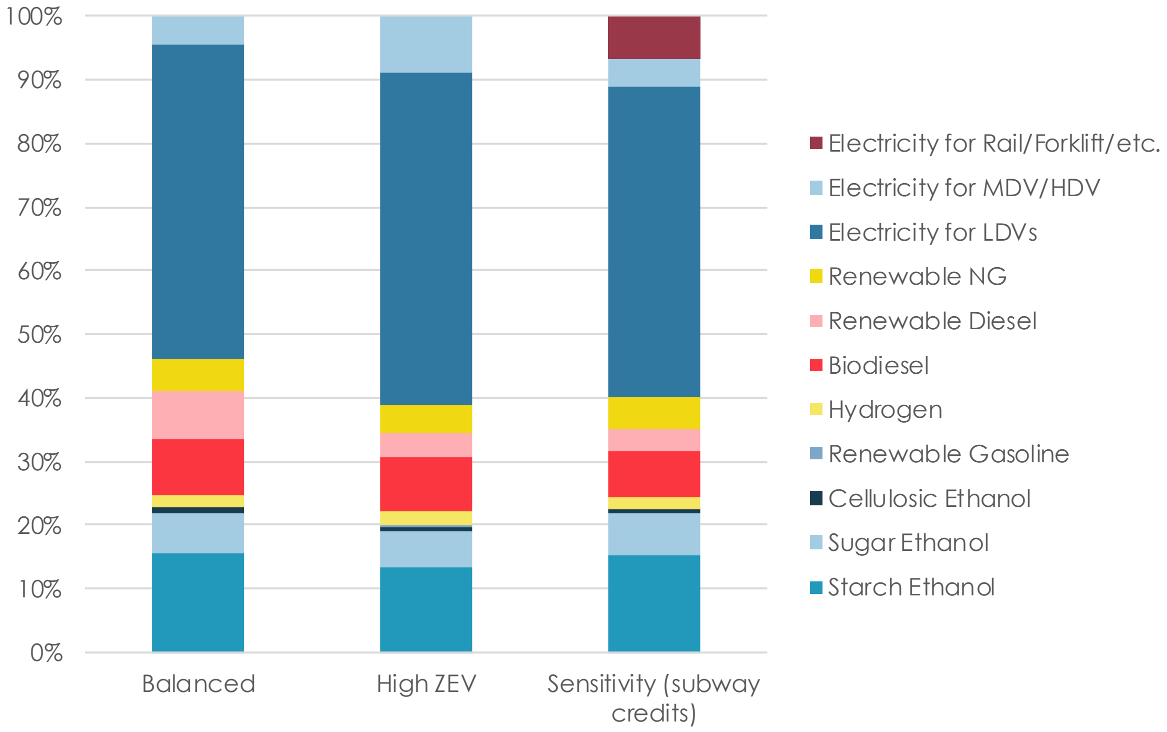

Figure 18. Sources of credit generation in the three scenarios

7. Potential air quality benefits

Alongside the climate benefits of an NY-LCFS, reducing the combustion of fossil fuels will deliver associated air quality and health benefits. In the *balanced* scenario, 2030 consumption of fossil diesel is reduced by 320 million gallons compared to the baseline, while consumption of gasoline is reduced by 120 million gallons. Some of this reduction is associated with switching to other ICE fuels (renewable diesel, ethanol, biodiesel, renewable natural gas) and some is associated with increased sales of ZEVs. Detailed modeling of the air quality and health impacts of these changes is beyond the scope of this report, but an indication of the benefits and their monetized value can be estimated by considering the implied change in absolute emissions of key pollutants (NOx and PM2.5) and by references to literature estimates of the monetized health impact of those pollutants per tonne released.

In analysis of the air quality impacts of the CA-LCFS (California Air Resources Board, 2018a) the main air quality impacts identified by CARB as attributable to the CA-LCFS come from blending biodiesel and renewable diesel in the diesel pool. Air quality benefits associated with expanding the ZEV fleet are considered in analysis of other regulations, notably the ZEV mandate. Renewable diesel results in NOx emissions reductions for older engines (without selective catalytic reduction, SCR) and PM2.5 emissions reductions for all engines.

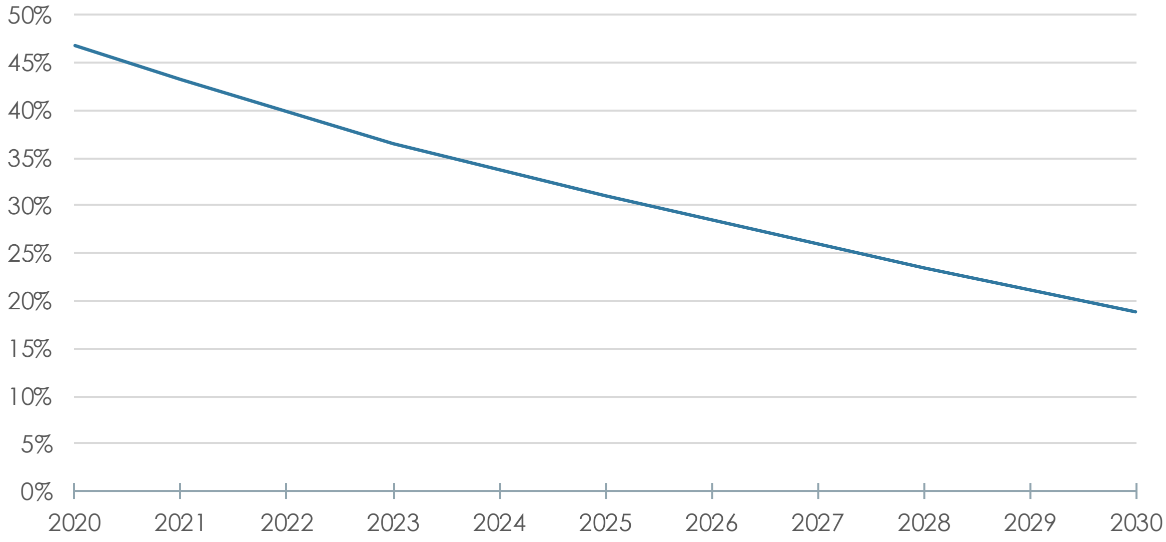

Figure 19. Modeled fraction of diesel consumed by engines without selective catalytic reduction

Note: this fraction is not sensitive to scenario choice.

Use of biodiesel leads to increased NOx emissions in older engines, but also reduces PM2.5 emissions. In assessing the impact on emissions of an NY-LCFS it is important to recognize that emissions are on a reducing trend already. For instance, as older diesel vehicles are retired from the fleet overall NOx emissions are reduced by increased use of SCR, which reduces the marginal air quality benefit of using renewable diesel. Figure 19 shows the estimated fraction for New York State (based on the VISION vehicle turnover modeling and assuming that vehicles sold after 2007 have SCR) of diesel fuel consumed in engines without SCR. The fraction decreases over the decade but remains significant even in 2030.

Using the CARB emissions change factors we calculate the overall change to diesel related NOx and PM emissions for the two scenarios. As shown in Figure 20 and Figure 21, both NOx and PM emissions are reduced by NY-LCFS, with PM reductions of 6% from diesel combustion by 2030 in the *balanced* scenario. NOx reductions from renewable diesel use more than offset the increase associated with increased biodiesel blending.

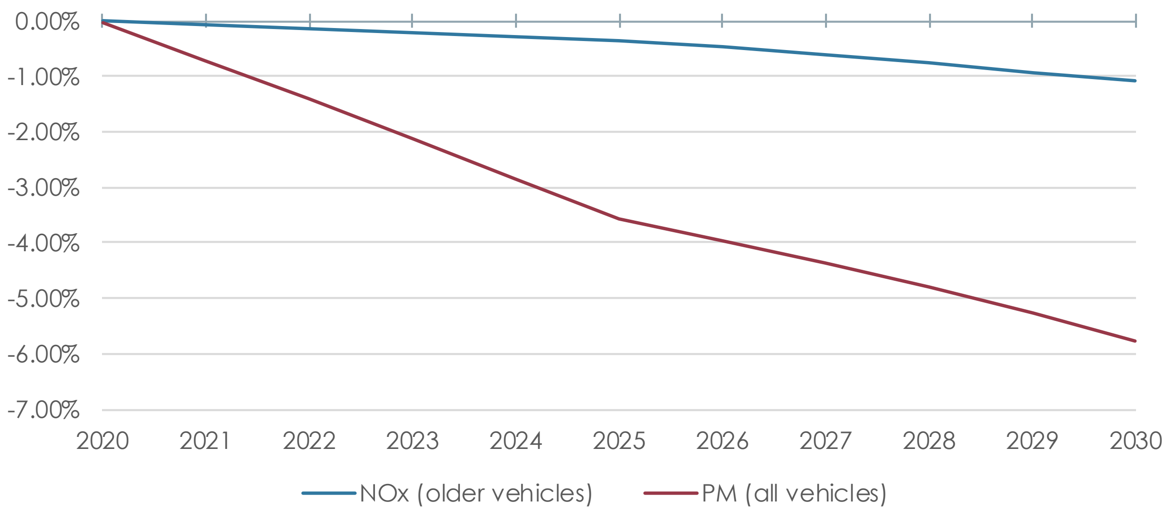

Figure 20. NOx and PM emissions reduction from additional alternative diesel use in the *balanced* scenario

Note: NOx benefits delivered only for older vehicles without selective catalytic reduction.

Using the estimation approach detailed in Annex A we have built on the California analysis (California Air Resources Board, 2018b) to derive estimates of total potential pollutant emission reductions from biodiesel and renewable diesel, and the associated monetized health benefits. We emphasize that there is considerable uncertainty in this simplified assessment, that results can be quite sensitive to details of assumptions in the fuel supply and air quality modeling, and that therefore the results should be treated as indicative only.

In the *balanced* scenario, cumulative NOx emissions to 2030 are reduced by about 1,300 tonnes by the use of biodiesel and renewable diesel, associated with a monetized health benefit of $11 million. Cumulative PM2.5 emissions to 2030 are reduced by about 800 tonnes, associated with a monetized health benefit of $500 million.

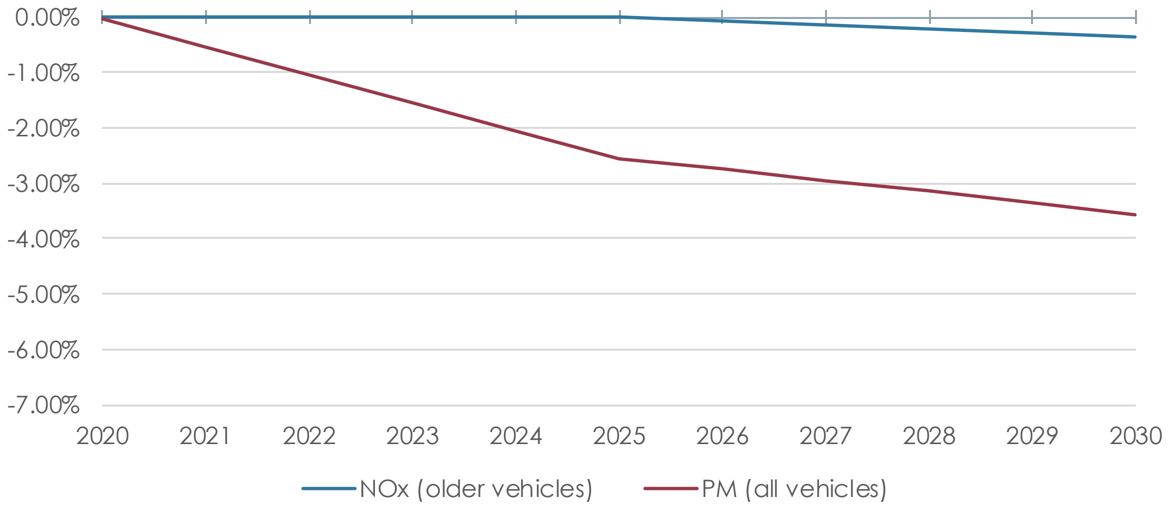

Figure 21. NOx and PM emissions reduction from additional alternative diesel use in the *high ZEV* scenario

Note: NOx benefits delivered only for older vehicles without selective catalytic reduction.

Additional NOx and PM2.5 emissions reductions are delivered by the expansion of the electric vehicle fleet. Increased use of medium- and heavy-duty EVs is estimated to reduce cumulative NOx emissions by about 2,300 tonnes, with an associated monetized health benefit of $25 million, and to reduce cumulative PM2.5 emissions by about 500 tonnes, with an associated monetized health benefit of about $350 million. On the passenger vehicle side, increased ZEV populations reduce cumulative NOx emissions by about 1,400 tonnes, with an associated monetized health benefit of $14 million, while cumulative PM2.5 emissions are reduced by about 100 tonnes, with an associated monetized health benefit of $60 million. Note that these monetized health benefits reflect the air quality improvement over the baseline, and that the overall air quality benefit from the use of alternative fuels and vehicles is larger.

Changes in other criteria pollutant emissions, changes associated with increased use of ethanol and natural gas, and changes associated with upstream fuel production and with fuel processing and distribution were not considered, but are expected to be comparatively minor. Overall air quality benefits are similar but larger in the *high ZEV* scenario, primarily due to the assumed higher medium- and heavy-duty EV displacing more diesel fuel.

7.1. Implications for disadvantaged communities

Air quality improvements tend to be of particular benefit to disadvantaged (California Air Resources Board, 2019) communities, because disadvantaged communities in New York State are likely to have greater exposure to pollutants from on-road sources (Clark, Millet, & Marshall, 2014; Union of Concerned Scientists, 2019; Woo et al., 2019). The health benefits from reduced on-road pollution, and in particular from reduced PM and NOx pollution from diesel fuel use, can be expected to accrue disproportionately to disadvantaged communities, in particular those in urban areas. This would be true even if these communities were not directly using lower emissions vehicles, but the benefits could be further leveraged by seeking to accelerate ZEV deployment in these areas.

California, both in the CA-LCFS and in its broader ZEV support programs, provides examples of actions that could be taken to increase the benefits from electrification to disadvantaged communities, both by encouraging EV ownership for private individuals, and by preferentially supporting deployment of electric buses and other heavy duty vehicles in disadvantaged areas and areas most affected by pollution. Similar targeting is in place for the New York State voucher program. California Governor’s Executive Order B-48-18 created a goal to “expand private investment in zero-emission vehicle infrastructure, particularly in low income and disadvantaged communities”, and measures to deliver on this goal are detailed in the 2018 update to the California ZEV Action Plan (State of California, 2018).

Within the CA-LCFS, the main action being taken relates to the use of revenue received by electric utilities from residential electric vehicle charging credits. CA-LCFS program amendments proposed in October 2019 (California Air Resources Board, 2019) include a measure requiring public utilities to utilize CA-LCFS credit revenues not invested in the “Clean Fuel Reward” electric vehicle rebate program to support access to electric transportation in disadvantaged communities - it is proposed that by 2024 at least 50% of this ‘holdback’ credit value should be invested in such projects. Under an NY-LCFS, if similar rules were introduced to those in effect in California[25] this could deliver $25 million in annual funding by 2024, and over $100 million by 2030 (*balanced* scenario). That is comparable to the full amount of funding available for the current round of the NYTVIP scheme (NYSERDA, 2020).

Further suggested actions in the California ZEV Action Plan include:

- Develop a short summary of findings detailing statistics and outcomes of state investments in car sharing programs in low-income and disadvantaged communities and provide suggestions to improve access to ZEVs through car sharing in these communities.
- Improve awareness and accessibility of ZEV technologies, benefits, and opportunities in low-income and disadvantaged communities by developing and implementing a comprehensive clean transportation outreach plan and the One-Stop-Shop Pilot Project.
- Public utility supported charging station expansion with 10% of infrastructure and expenditures in disadvantaged communities.
- Electric Vehicle Charging Station Financing program providing a loan loss reserve for eligible borrowers to finance the acquisition and installation of PEV chargers at small businesses, multi-unit dwellings, and in disadvantaged communities.
- Locating demonstration and pilot deployment projects of zero emissions medium- and heavy-duty vehicle technology in disadvantaged areas.
- Identify appropriate approaches for utility investment in education and outreach

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[25] Assume 80% of charging is residential (https://www.energy.gov/eere/electricvehicles/charging-home) and two thirds of residential charging credits are invested into unrestricted ZEV rebates (cf. State of California, 2019).

programs that build awareness of ZEVs in low-income, moderate-income and disadvantaged communities.

- Support zero-emission school bus deployments, especially in low-income and disadvantaged communities, throughout California.
- Increase availability of PEV charging and hydrogen fueling stations in areas of low PEV and FCEV adoption and in disadvantaged communities.
- Explore funding options for PEV charging infrastructure installations in disadvantaged, low- and moderate-income communities and neighborhoods with a high concentration of MUD complexes.

NY-LCFS revenue could be leveraged to support similar actions in New York State (recognizing of course that while these are significant revenues, they are not unlimited and not everything could be funded).

8. Financial impacts

As with any program of incentives and disincentives, introducing an NY-LCFS will have cost implications for some affected by the program, while creating opportunities for savings for others. It is fundamental to the concept of a low carbon fuel standard that a burden is imposed on suppliers of fossil fuels (and, as some or all costs of NY-LCFS compliance will be passed through, on consumers of fossil fuels) to support the development and deployment of lower carbon transportation energy alternatives. The transition to lower carbon intensity energy does not only bring costs, however, but a range of potential benefits. For example, while the cost of purchasing natural gas or electric vehicles is currently higher than conventionally fueled alternatives, many studies have shown that total lifetime cost of ownership can be lower due to the lower cost of refueling with natural gas or electricity. As discussed above, compliance with an NY-LCFS is expected to deliver air quality co-benefits that can be monetized. The additional CO_2 emissions reductions associated with adopting an LCFS can also be monetized and treated as a benefit.

In this section, we review some of the potential impacts and financial flows that could be driven by an NY-LCFS in the period 2020-2030. Potential financial impacts associated with an NY-LCFS include:

1. Energy cost savings for vehicle operators switching to electric vehicles or natural gas vehicles;
2. Higher fuel costs associated with replacing diesel with biodiesel and renewable diesel;
3. Higher fuel costs associated with fuel cell vehicles[26];
4. Higher costs in the near-term for ZEV purchases compared to conventional vehicle purchases;
5. Potentially reduced costs for some ZEV purchases compared to electric vehicles by 2030;
6. LCFS credit revenue available to electric utilities to support deployment of electric vehicles;
7. Costs borne by liquid fuel consumers to support LCFS credit purchases by fuel suppliers;
8. Shift of revenues from fossil fuel refiners to low carbon fuel producers due to fuel switching;
9. Transfer of part of the cost of supporting vehicle electrification from other taxpayers/vehicle manufacturers to liquid fuel consumers;
10. Monetized health benefits from air quality improvement;
11. The social value of reduced overall CO_2 emissions.

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[26] Hydrogen costs are higher based on the price projections in VISION even given increased energy efficiency of FCVs.

The attribution of costs and benefits to an NY-LCFS is sensitive to assumptions made about the baseline (cf. Annex A), i.e. assumptions about what would happen in the absence of the policy. For electric vehicles in particular, it is difficult to confidently attribute a given share of sales to any one of the policies that support them. In the scenario analysis, it is assumed by hypothesis that a NY-LCFS delivers marginal additional passenger and medium/heavy duty sales, and in the financial assessment we focus on the costs and benefits associated with those marginal changes. One should however be cautious of considering NY-LCFS on its own without reference to the broader set of climate and ZEV support policies in New York State and in the country as a whole. For example, using LCFS credit revenue to fund a program of EV purchase rebates could be seen as additional spending at a cost to fossil fuel consumers, but could also be seen as an alternative to the use of taxpayer funds to support electrification, thereby delivering a financial benefit to taxpayers. If the NY-LCFS can be used to support EV deployment that would be supported by alternative programs in its absence, it becomes very challenging to confidently identify what is the true baseline case. As in the discussion of health benefits above, we emphasize again that the results presented in this section are sensitive to numerous assumptions about energy and vehicle prices, rates of deployment of each NY-LCFS compliance options, competition in the market and policy design, and should be treated as indicative rather than predictive.

8.1. *Balanced* NY-LCFS compliance scenario

In both of the compliance scenarios considered, the largest financial changes relate to expansion of the electric vehicle fleet, primarily passenger vehicles. Switching from ICEs to EVs delivers a significant cost saving to drivers because of the greater efficiency of the electric drivetrain. In the *balanced* scenario, the ZEV fleet in New York State increases to 1.7 million vehicles by 2030. By 2030 this results in a $1.7 billion annual reduction in transportation energy expenditures compared to the use of conventional liquid fuels. Given that the baseline considered for the financial analysis already includes significant EV market growth, only part of this is attributed to LCFS. The *balanced* scenario sees an additional 220 thousand passenger ZEVs and 13 thousand medium- and heavy-duty ZEVs on the road, associated with **$290 million of transportation energy cost savings** in 2030, with $1.4 billion of cumulative savings from 2020 to 2030. These savings are accrued by owners/users of electric vehicles.

While the cumulative energy cost savings in the period modeled for the NY-LCFS are substantial, there are also ongoing cost savings to be expected after 2030, as the electric vehicles that are deployed in response to the price signal from a NY-LCFS would remain on the road for some years to come. The ongoing savings from reduced energy prices from all ZEVs are estimated to reach a further $3 billion.

There are also costs associated with buying ZEVs instead of conventional vehicles. Based on the Lutsey & Nicholas (2019) cost assessments discussed above for BEVs and PHEVs, additional annual spending on new battery electric passenger vehicles could reach $450 million by 2023, of which $60 million is attributed to the NY-LCFS in the *balanced* scenario. These purchases could be supported through the disbursement of the roughly $100 million available to electric utilities from NY-LCFS credit revenues in that year. Reductions in battery EV costs over time (assuming that costs develop in line with the ICCT predictions) mean that the overall additional costs of passenger EV purchases reduce after 2023, and from 2028 total costs of new EV purchases are lower than for comparable conventional vehicles. By 2030 the annual saving on new vehicle purchases from choosing battery electric vehicles is estimated at around $800 million, of which $110 million is attributed to the NY-LCFS. This does not include the savings from reduced costs of refueling.

NY-LCFS credit revenues could make a major contribution to supporting battery electric vehicle sales through funding purchase rebates. As shown in Figure 22, the scale of NY-LCFS credit revenue is expected to be comparable to the additional cost of PV EV purchases. It is notable, however, that the largest NY-LCFS credit revenues are expected later in the program (as there are more PV EVs on the road by then, and higher assumed credit prices); at which point EV sales prices are expected to have gone below parity with ICEs for all EV types. This suggests that mechanisms to bring rebate spending forward, for instance by borrowing against future credit generation, should be considered.

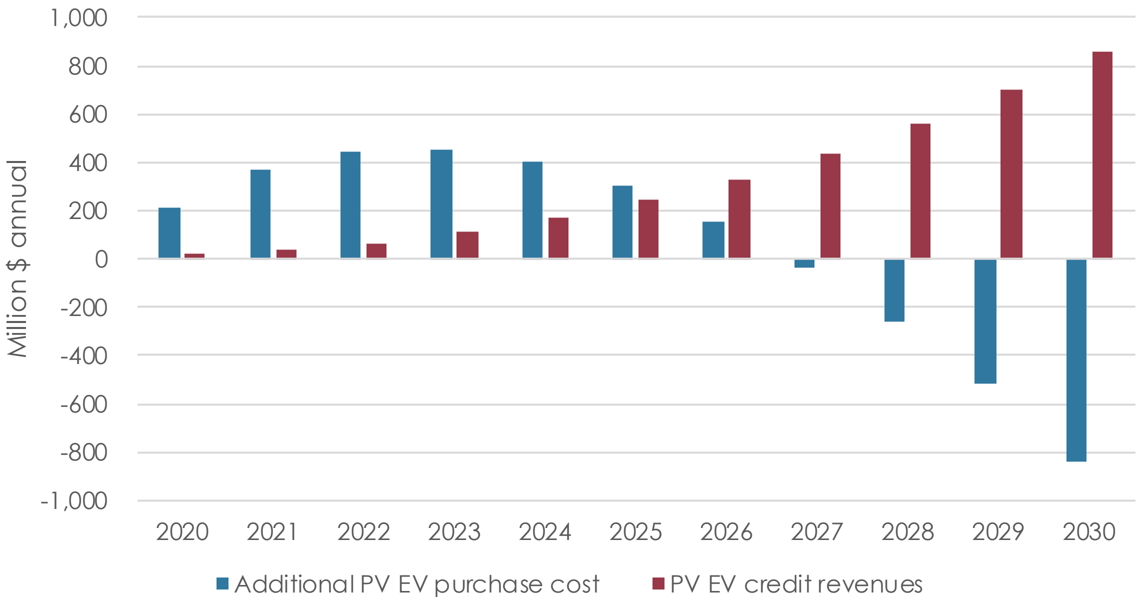

Figure 22. Marginal costs of purchasing electric vehicles compared to modeled annual revenues from NY-LCFS credits for PV EV charging (*balanced* scenario)

Despite these reductions in purchase prices later in the program, the total additional expenditure on electric vehicle purchases attributed to NY-LCFS in the period 2020-2030 is estimated at about $74 million. These additional purchase costs are an order of magnitude lower than the estimated savings from recharging with electricity instead of using liquid fossil fuels.

As noted above, additional costs would also be incurred from the shift to natural gas and electric medium- and heavy-duty vehicles. A cumulative additional $650 million is spent on vehicle purchases over the period 2020-30 (about $350 million extra on natural gas vehicles, and $300 million extra on EVs). Note that we have not identified comparable projections for the additional purchase costs for fuel cell vehicles, and these have therefore not been assessed.

Switching to renewable natural gas delivers further energy cost reductions, even with the assumed cost of demonstrating renewability. A cumulative $500 million is saved by operators of medium- and heavy-duty natural gas vehicles on fuel costs (compared to using diesel fuel), although these savings would be partly offset by the increased vehicle purchase prices mentioned above.

While the use of electricity and natural gas results in reductions in expenditure on transportation energy, increased use of lower carbon intensity fuels including ethanol, biodiesel and renewable diesel are expected to result in increases to energy costs for consumers of liquid fuels. In the gasoline pool, the scenario assumes a modest increase in average in ethanol blending to E12.5 and an additional cost to source lower carbon intensity ethanol. The shift in ethanol sourcing would add 0.8% to the price of blended gasoline in 2030. The impact on the diesel pool in this scenario is larger due to the relatively high reliance on renewable diesel to deliver emission reductions, alongside the increase in biodiesel volume. The higher cost of biodiesel and renewable diesel fuels add about $500 million to diesel-pool fuel expenditure in 2030. Renewable diesel is in fact one of the largest sources of increased fuel costs in the model, associated with $1.8 billion of cumulative additional expenditure. This is driven by the relatively high volume, high cost per gallon and middling carbon intensity assumed for renewable diesel, 90% of which is assumed to be soy and canola based.

8.2. *High ZEV* NY-LCFS compliance scenario

As in the *balanced* scenario, switching from ICEs to EVs delivers a significant cost saving to drivers because of the greater drivetrain efficiency. The ZEV fleet in New York State increases to 1.8 million vehicles by 2030. By 2030 this results in a $1.9 billion annual reduction in transportation energy expenditures compared to the use of conventional vehicles. Given that the baseline considered for the financial analysis already includes significant EV market growth, only part of this is attributed to LCFS. The *high ZEV* scenario sees an additional 400 thousand passenger ZEVs (a 25% increase on the baseline) and 35 thousand medium- and heavy-duty ZEVs on the road compared to the baseline, associated with **$530 million of NY-LCFS-attributed transportation energy cost savings** from electric vehicle use in 2030, with $2.5 billion of cumulative savings from 2020 to 2030.

With increase electric vehicle sales come increased vehicle purchase costs until EVs reach price parity with ICE vehicles. The *high ZEV* scenario drives up to $100 million of additional annual spending on vehicle purchases compared to the baseline (2023), but reductions in EV costs below the cost of conventional vehicles provide a $200 million reduction in vehicle purchase costs attributed to the NY-LCFS in 2030. The total net additional expenditure on electric vehicle purchases attributed to NY-LCFS in the period 2020-2030 is estimated at about $75 million[27]. The cumulative additional purchase cost for natural gas and electric medium- and heavy-duty vehicles is estimated at $900 million. As in the *balanced* scenario the overall savings on energy costs from electric vehicles outweigh the additional purchase costs.

In the gasoline pool, the high-ZEV scenario sees very similar results to the *balanced* scenario. Sourcing lower carbon intensity ethanol adds 0.7% to the price of E10 blend gasoline in 2030. The impact on the diesel pool is moderated by reduced reliance on renewable diesel, and the higher cost of biodiesel and renewable diesel fuels are associated with $170 million of

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[27] This is lower than the cumulative additional costs attributed to the *balanced* scenario, reflecting the offsetting effect of savings on vehicle purchase prices after 2027.

additional fuel expenditure in 2030. Savings from the use of natural gas are slightly lower than in the *balanced* scenario, about $400 million cumulatively.

8.3. Sensitivity: crediting for NYC subway

In the sensitivity case, crediting electricity consumption by the New York City subway brings additional credits into the system at no marginal cost (we do not assume that crediting affects the number of journeys made on the subway) allowing for the target to be met with a reduction in the supply of liquid and gaseous fuels as compared to the *balanced* scenario. Reducing renewable diesel consumption to the same level as assumed in the *high ZEV* scenario reduces modeled cumulative costs by $1 billion and reducing the biodiesel blend to B5 reduces fuel costs by a further $300 million, but simultaneously results in a reduction in monetized health benefits by $400 million and monetized climate benefit by $200 million.

8.4. Discussion on financial implications

When considering the adoption of an NY-LCFS, policy makers will rightly be interested in understanding how the costs and benefits for such a program compare. As stated above when introducing the cost assessment methodology, the results reported here do not constitute a full cost benefit analysis, but we hope that they do at least provide a meaningful indication of the financial implications of an NY-LCFS policy. Table 3 provides a summary of the cost implications assessed for the two scenarios. The value of CO_2 emission reductions from an NY-LCFS have been added assuming a social cost of CO_2 of $50 per tonne (U.S. EPA, 2016), again considering only additional carbon savings beyond those in the baseline.

Table 2. Cumulative cost implications 2020-2030 of an NY-LCFS

	Balanced	High ZEV	Sensitivity
Additional cost of renewable diesel supply	-1.8	-0.8	-0.8
Additional cost of ethanol and biodiesel supply	-1.1	-1.0	-0.8
Savings from electricity for BEVs/PHEVs, 2020-2030	1.4	2.5	1.4
Additional cost of hydrogen for FCVs	-0.2	-0.4	-0.2
Ongoing refueling savings from ZEVs	3.0	5.8	3.0
Savings from use of natural gas	0.5	0.4	0.5
Additional cost of passenger PHEV/BEV purchases	-0.1	-0.1	-0.1
Additional cost of MD/HD BEV purchases	-0.6	-0.9	-0.6
Estimated monetized health benefits	0.8	1.0	0.4
Monetized climate benefits at $50 per tCO2e	1.2	1.3	1.0
Net benefit on impacts considered	**3.1**	**7.9**	**3.8**
Other impacts not assessed: cost of FCVs; reduced cost of other ZEV programs; other criteria pollutant reductions; induced economic effects.			

It is apparent from Table 3 that we expect an NY-LCFS to be more economically efficient the higher the contribution of electric vehicles to compliance is. This should not be surprising, as it is well documented that as purchase prices reduces electric vehicles will offer an increasing advantage on a total cost of ownership basis against conventional vehicles. By the end of the decade, passenger electric vehicles are expected to be cheaper, much more efficient, and cleaner than ICE vehicles. In contrast, while renewable diesel has appeal as a compliance option due to being free of a blend limit it is expected to remain a relatively expensive fuel, associated with more modest air quality benefits and not associated with significant efficiency improvements.

Alongside these net costs and benefits an NY-LCFS would drive financial transfers from gasoline and diesel consumers to electric and natural gas vehicle users, through the purchase of credits. By 2030, that represents a $900 million annual transfer to support ZEVs and a $70 million annual transfer to support natural gas.

There are also a range of broader financial impacts to be expected from an NY-LCFS, as the economy adjusts to new fuel and vehicle production pathways. In the period 2020-2030, cumulative fossil fuel sales are reduced by nearly $8 billion, with an additional $10 billion of expenditure on alternative energy. If that supports in-state production of biofuels, renewable natural gas and electricity instead of out of state oil extraction, it could deliver economic benefits to New York State that are not captured in this study.

9. Conclusions

This report presents two scenarios demonstrating that a 20% carbon intensity reduction target for New York State transportation is achievable in principle under an NY-LCFS. Meeting such targets would require significant investments changes in the energy supply system, but nothing that appears unachievable if the right mechanisms are put in place to deliver change. As will be the case in the CA-LCFS to 2030, one result that emerges very clearly from the analysis is that an NY-LCFS would not be a program driven primarily by biofuel sales, but would be extremely sensitive to the development of the electric vehicle market (and associated infrastructure) in the state. This reliance on electric vehicles to meet targets leads us naturally to ask how an NY-LCFS could be made not only dependent on electric vehicle deployment but be made an effective driver of electric vehicle deployment. This mutual dependency is not a necessary feature of an LCFS policy. In the original design documents for the ~CA-LCFS, it was noted that, "the LCFS also does not necessarily provide sufficient support for advanced vehicle technologies that will likely be required for the success of some vehicle-fuel combinations, such as battery electric vehicles (BEVs) and hydrogen fuel cell vehicles (HFCVs)" (Farrell, Sperling, Brandt, et al., 2007).

California is just starting to roll out policy instruments to make the CA-LCFS a more effective driver of electrification, and New York has the opportunity to move directly to implementing comparable measures when an NY-LCFS is adopted. As we have shown in this report, the credit value from a NY-LCFS would be well suited to supporting electric vehicle purchase rebates, but the size and effectiveness of such rebates will be sensitive to aspects of policy design. As it stands, a new electric vehicle sold into the California market would more than pay back its rebate in credit generation over its operational lifetime. Policy makers should consider whether mechanisms are available to bring more of that value forward to accelerate deployment, for instance through developing financing mechanisms to support borrowing against future credit generation.

A necessary corollary of the interdependency between an NY-LCFS and the ZEV market is that NY-LCFS credit markets will be sensitive to ZEV roll out, even though the exact rate of deployment is partly independent of low carbon fuel policy. NY-LCFS policy design should accept this reality and seek to build resilience against both the case that ZEV deployment moves faster than expected, and the case that it moves much more slowly. Appropriate cost containment mechanisms (such as the California credit clearance market) can be used to cap potential credit prices. It is arguably more difficult to provide protection against low credit prices, and the possibility that investments made in good faith will fail if high rates of ZEV deployment cause a collapse in NY-LCFS credit prices. Given the urgent need to reduce CO_2 emissions as quickly as is economically responsible, one answer to this conundrum would be for the State to keep open the possibility of increasing targets if the market will support it. Another option might be to consider enforced banking of some portion of base charging credits in later years of the program if credit supply temporarily outstrips demand.

If New York State does introduce an NY-LCFS, there will be numerous decisions to be made to allow effective implementation. These will include setting compliance trajectories, defining eligible pathways, setting baseline carbon intensities and placing any conditions on base charging credits. All of those decisions are important, and we would expect that elements of the program will end up being quite different to what is modeled here. We hope that policy makers find a balance between targets that are ambitious while being achievable, and that

New York is able to hit the ground running with a portfolio of measures to maximize the impact of credit revenues.

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Annex A. Baseline

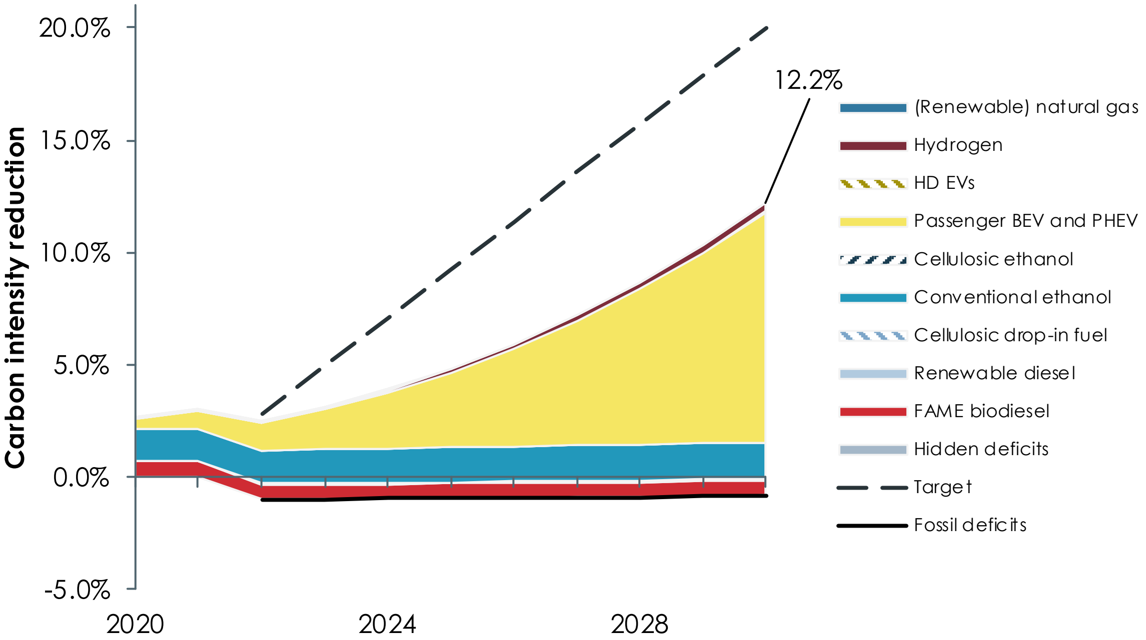

Figure 23. Carbon intensity reductions in the baseline scenario

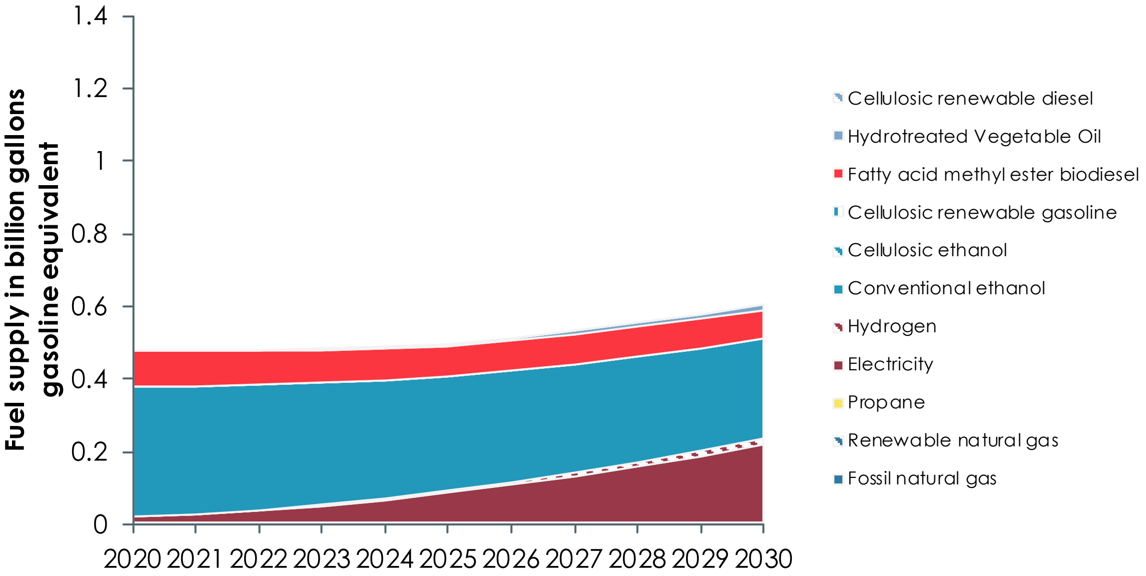

Figure 24. Energy supplied as alternative fuel in the baseline

Annex B. Air quality

This report presents first order estimates of potential air quality benefits from the adoption of an NY-LCFS. This assessment is based on adaptation of analysis undertaken for the CA-LCFS, and monetized benefits are based on simple factors for benefit per tonne of avoided emissions without any detailed modeling of the specific New York State context. These estimates should therefore be treated only as indicative of the potential magnitude of benefits. Applying a full suite of air quality and health benefit modeling tools with New York State specific factors was beyond the scope of this paper.

Potential reductions in NOx and PM pollution due to reduced combustion of fossil diesel fuel are estimated following the outline approach detailed by California Air Resources Board (2018a). The potential reduction in NOx and PM from the increased use of electric vehicles, natural gas vehicles, renewable diesel and biodiesel[28] are calculated using a modified version of the air quality calculations in California Air Resources Board (2018b). The emissions model is calibrated to New York rates of diesel-associated NOx and PM2.5 emissions using EPA data for 2014 (U.S. EPA, 2018). It is assumed that the baseline evolution of these emissions in New York follows the evolution assumed in the California analysis (e.g. NOx emissions are reduced over time in the baseline by the roll out of ‘new technology diesel engines’). This would have been a reasonable assumption for total on-road emissions over the preceding ten years, as shown in Figure 25.

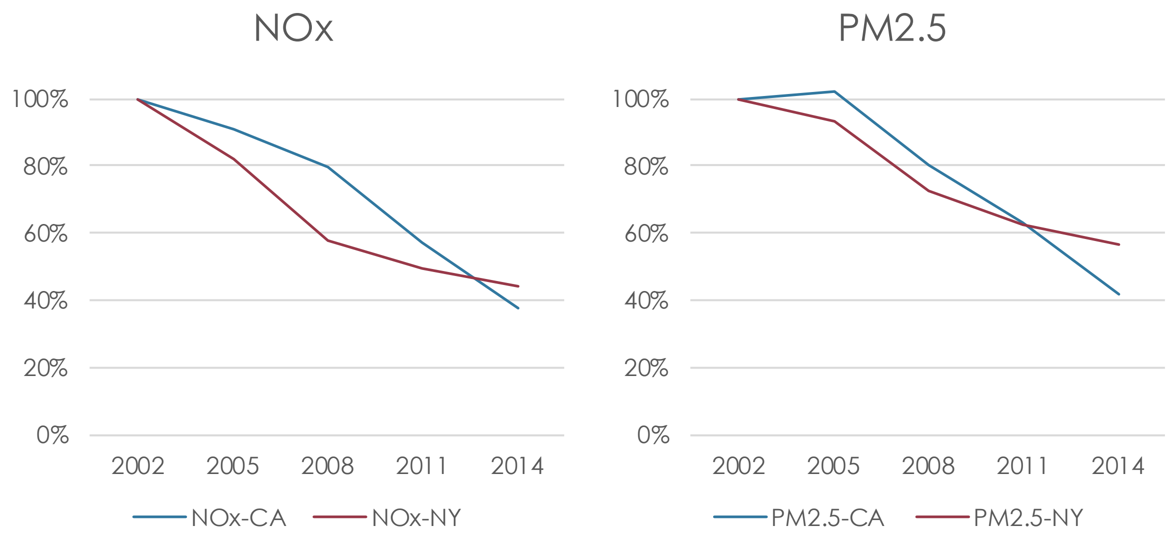

Figure 25. Evolution of on-road emissions of NOx and PM 2.5 in NY and CA, 2002-2014, normalized to 2002 levels

Reduced NOx and PM emissions from reduced diesel use due to above-baseline deployment of heavy-duty electric-drive vehicles are added to the model. Changes in criteria emissions

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[28] Increased biodiesel use is expected to cause an increase in NOx emissions, but these marginal increases are more than compensated by reductions from other LCFS credit generation pathways.

associated with increased use of natural gas vehicles are not considered in California Air Resources Board (2018a) and have not been estimated.

Estimates for the monetized value of NOx and PM2.5 reductions per tonne of emissions are taken from Wolfe et al. (2019). Cost estimates are reported based the average across two sets of mortality data (Krewski et al., 2009; Lepeule, Laden, Dockery, & Schwartz, 2012).

Table 3. Monetized impact per tonne of PM2.5/NOx pollution, east of the U.S.

	PM2.5		NOx	
	Krewski	Lepoule	Krewski	Lepoule
Non-road (average)	$422,857	$957,143	$4,943	$11,086
Heavy duty on-road diesel	$360,000	$820,000	$6,500	$15,000

Gasoline engines in New York are responsible for total levels of PM2.5 emissions comparable to those from diesel engines, and thus replacing these vehicles with electric drive vehicles will provide additional air quality benefits. Emissions of NOx and PM from gasoline vehicles in New York State are taken from U.S. EPA (2018). It is assumed that criteria pollutant emissions will continue to reduce in the baseline due to engine improvements. Expected emissions rates in the period to 2030 are extrapolated on an exponential trend from average light duty per-vehicle emissions documented by Bureau of Transportation Statistics (2019). Emission reductions are calculated based on the volume of additional gasoline use displaced in the LCFS scenarios as compared to the baseline scenario. Upstream emissions from electricity production are not considered, but are likely to be small compared to on-road emissions, and reduce with increase renewable electricity use. As with the diesel pool, the value of emissions reductions is calculated using the average values from Wolfe et al. (2019) averaged across the two mortality estimates (Krewski et al., 2009; Lepeule et al., 2012).