# Technical Appendix – Modeling Assumptions for Freight Pathway Components

Freight pathways evaluated by GNA in the report "Moving California Forward: Zero and Low-Emission Goods Movement Pathways" included estimated upstream and downstream emissions of NOx, PM, and GHGs. These emissions estimates are an aggregation of estimated emissions for each component in the modeled freight pathway. Table 1 summarizes all of the freight pathway components and associated emissions estimates that were developed as part of this modeling exercise. Not all pathway components were included in the main report as the priority freight pathways did not necessarily use every possible technology combination. All pathway components are reported here for completeness.

Conceptually, a pathway component is an activity, or group of activities, to which emissions estimates can be attributed based on available literature and inventory data. Pathway components vary in their level of granularity. For example, "on-dock rail activity" includes all switcher and linehaul locomotive emissions associated with idling, train building, and loading that occur on port property. This pathway component obviously includes emissions contributions from numerous types of equipment and operations. By contrast, the various "short range drayage truck" pathway components reflect activity associated with a single type of vehicle performing a relatively limited set of activities (on-road trucking). However, in both cases the pathway components are based on emissions inventory data that can reasonably be attributed to the described pathway component without attempting to subdivide the pathway component further than allowed by the available data.

This appendix summarizes the major assumptions and data sources used to develop the emissions estimates for each freight pathway component. These descriptions are meant to accompany the spreadsheet used to model the emissions and are not intended to be a detailed and exhaustive reporting of the methodologies employed. The reader is encouraged to reference the spreadsheet in regard to detailed questions associated with calculations, emissions factors, and other specific data.

Table 1. Emissions estimates for components of freight pathways

| ID | Freight Pathway Components | Downstream Emissions (g/ton-mile) | | | Upstream Emissions (g/ton-mile) | | | Total Emissions (g/ton-mile) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | NOx | PM | GHGs | NOx | PM | GHGs | NOx | PM | GHGs |
| 1 | POLA Diesel Short Range Drayage Truck | 0.735 | 0.012 | 154 | 0.094 | 0.007 | 42.9 | 0.829 | 0.019 | 197 |
| 2 | POLA NG Short Range Drayage Truck | 0.735 | 0.012 | 148 | 0.064 | 0.003 | 56.7 | 0.799 | 0.014 | 205 |
| 3 | OAK Diesel Short Range Drayage Truck | 0.77 | 0.010 | 156 | 0.095 | 0.007 | 43.4 | 0.86 | 0.017 | 199 |
| 4a | OAK NG Short Range Drayage Truck | 0.77 | 0.010 | 150 | 0.064 | 0.003 | 57.2 | 0.83 | 0.013 | 207 |
| 4b | MY2007 Diesel Short Range Drayage Truck | 0.807 | 0.012 | 155 | 0.094 | 0.007 | 42.9 | 0.900 | 0.019 | 198 |
| 5 | MY2010 Diesel Short Range Truck | 0.366 | 0.011 | 150 | 0.091 | 0.007 | 41.8 | 0.457 | 0.018 | 192 |
| 6a | MY2010 NG Short Range Truck | 0.366 | 0.011 | 144 | 0.062 | 0.003 | 55.1 | 0.428 | 0.014 | 199 |
| 6b | Advanced NOx Standard Diesel Short Range Drayage Truck | 0.073 | 0.011 | 150 | 0.091 | 0.007 | 41.8 | 0.164 | 0.018 | 192 |
| 7 | Diesel Regional Truck | 0.42 | 0.007 | 148 | 0.090 | 0.007 | 41.2 | 0.51 | 0.014 | 189 |
| 8 | NG Regional Truck | 0.42 | 0.007 | 142 | 0.061 | 0.003 | 54.4 | 0.48 | 0.010 | 197 |
| 9 | BEV Short Range Drayage Truck (CA Avg Grid Mix, 2020) | 0.000 | 0.000 | 0.000 | 0.004 | 0.001 | 26 | 0.004 | 0.001 | 25.8 |
| 10 | FCV Short Range Drayage Truck (80% NG, 20% Renewables) | 0.000 | 0.000 | 0.000 | 0.074 | 0.016 | 96 | 0.074 | 0.016 | 96.3 |
| 11 | Catenary Diesel Short Range Drayage Truck | 0.000 | 0.000 | 0.000 | 0.004 | 0.001 | 26 | 0.004 | 0.001 | 25.8 |
| 12 | PHEV Short Range Drayage Truck (100% electric operation) | 0.000 | 0.000 | 0.000 | 0.004 | 0.001 | 26 | 0.004 | 0.001 | 25.8 |
| 13 | POLA/POLB CHE (g/ton) | 2.46 | 0.051 | 1,258 | 0.670 | 0.050 | 307 | 3.13 | 0.102 | 1,566 |
| 14 | Rail Yard CHE (g/ton) | 2.82 | 0.067 | 1,258 | 0.670 | 0.050 | 307 | 3.49 | 0.117 | 1,566 |
| 15 | On-dock Rail Activity (Tier 3 switch + Tier 2 Line haul) (g/ton) | 9.24 | 0.256 | 759 | 0.404 | 0.030 | 185 | 9.65 | 0.286 | 944 |
| 16 | Tier 4 On-dock Rail Activity (g/ton) | 2.24 | 0.077 | 759 | 0.404 | 0.030 | 185 | 2.64 | 0.107 | 944 |
| 17 | Tier 2 Railyard Switching (g/ton) | 0.760 | 0.017 | 71.5 | 0.038 | 0.003 | 17.5 | 0.799 | 0.019 | 89.0 |
| 18 | Tier 4 Railyard Switching (g/ton) | 0.122 | 0.004 | 71.5 | 0.038 | 0.003 | 17.5 | 0.160 | 0.007 | 89.0 |
| 19 | Tier 2 Linehaul Rail | 0.322 | 0.009 | 22.4 | 0.012 | 0.001 | 5.48 | 0.334 | 0.010 | 27.9 |
| 20 | Tier 4 Linehaul Rail | 0.076 | 0.003 | 22.5 | 0.012 | 0.001 | 5.48 | 0.088 | 0.004 | 27.9 |
| 21 | Electrified Linehaul Rail | 0.000 | 0.000 | 0.000 | 0.002 | 0.000 | 11.1 | 0.002 | 0.000 | 11.1 |
| 22 | Hybrid Tier 4 Railyard Switching (g/ton) | 0.122 | 0.004 | 28.6 | 0.015 | 0.001 | 6.99 | 0.137 | 0.005 | 35.6 |
| 23 | Electrified On-dock Rail Activity (g/ton) | 0.000 | 0.000 | 0.000 | 0.057 | 0.007 | 273 | 0.057 | 0.007 | 273 |

| ID | Freight Pathway Components | Downstream Emissions (g/ton-mile) | | | Upstream Emissions (g/ton-mile) | | | Total Emissions (g/ton-mile) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | NOx | PM | GHGs | NOx | PM | GHGs | NOx | PM | GHGs |
| 24 | Electrified Railyard Switching (g/ton) | 0.000 | 0.000 | 0.000 | 0.003 | 0.000 | 14.1 | 0.003 | 0.000 | 14.1 |
| 25 | Electrified Freight Shuttle (CA Avg Grid Mix, 2020) | 0.000 | 0.000 | 0.000 | 0.002 | 0.000 | 11.1 | 0.002 | 0.000 | 11.1 |
| 26 | On-dock Rail Activity (Tier 4 hybrid switch + Tier 2 Line haul) (g/ton) | 2.24 | 0.077 | 552 | 0.294 | 0.022 | 135 | 2.53 | 0.099 | 687 |
| 27 | Hybrid Tier 4 Line Haul Rail | Not considered | | | | | | | | |
| 28 | NG Tier 4 Railyard Switching (g/ton) | 0.122 | 0.004 | 54.5 | 0.037 | 0.001 | 23.2 | 0.159 | 0.005 | 77.7 |
| 29 | NG Tier 4 Line Haul Rail | 0.076 | 0.003 | 17.1 | 0.011 | 0.0003 | 7.27 | 0.088 | 0.003 | 24.4 |
| 30 | Virtual Container Yards | Fixed 5% reduction in VMT for drayage trucks | | | | | | | | |
| 31a | Short Sea Shipping (Tier 2) | 0.167 | 0.003 | 16.4 | 0.009 | 0.001 | 4.07 | 0.176 | 0.003 | 20.5 |
| 31b | Short Sea Shipping (Tier 4) | 0.034 | 0.0005 | 16.4 | 0.009 | 0.001 | 4.07 | 0.043 | 0.001 | 20.5 |
| 32 | Truck on Flatbed Car Linehaul | 0.683 | 0.020 | 47.7 | 0.025 | 0.002 | 11.6 | 0.709 | 0.022 | 59.3 |
| 33 | Truck on Flatbed Car Switching (g/ton) | 1.62 | 0.035 | 152 | 0.081 | 0.006 | 37.1 | 1.70 | 0.041 | 189 |
| 34 | Tier 4 Truck on Flatbed Car Linehaul | 0.161 | 0.006 | 47.7 | 0.025 | 0.002 | 11.6 | 0.187 | 0.008 | 59.3 |
| 35 | Tier 4 Truck on Flatbed Car Switching (g/ton) | 0.259 | 0.008 | 152 | 0.081 | 0.006 | 37.1 | 0.340 | 0.014 | 189 |

## Common Assumptions

**Cargo Weight** Most emissions inventories provided emissions on an annual basis or a per mile basis, without reference to cargo weights. To produce emissions estimates on a grams/ton or grams/ton-mile basis, it is necessary to estimate the weight of cargo transported in terms comparable with the emissions inventory data. For example, emissions provided for a railyard facility are typically given in tons per year of pollutant. To estimate the grams of pollutant per ton of cargo, it is necessary to divide the annual emissions by the total tons of cargo handled at the facility in one year. In some cases, cargo tonnage data is available. More commonly, data for the number of containers, TEUs, or lifts is available. Hence, it is necessary to assume an average container weight to ultimately produce an emissions estimate of grams/ton or grams/ton-mile of cargo. This modeling exercise assumed an average container weight of 10.6 tons, based on the reported average container weight for the Port of Los Angeles and Port of Long Beach. Fully loaded containers can be significantly heavier, with maximum rated capacities of up to 32.5 tons, however, many containers are transported lightly loaded depending on the cargo and many containers in transit are empties being returned to the ports for export. It is also important to note that this "average container" represents a forty foot container, not a TEU.

**Upstream Emissions** Argonne National Labs GREET 2012 model is used to estimate upstream emissions for all freight components. To calculate upstream emissions, fuel consumption rates are calculated and converted to an mmBTU basis, using the GREET model assumptions for the energy content of various fuels. Emissions associated with "Feedstock" and "Fuel", as reported by GREET, are then summed and reported for NOx, PM, and GHGs. Diesel fuel is estimated to have a 10% lower carbon intensity than 2010 levels due to the implementation of the LCFS. Natural gas carbon intensity is not assumed to change. Downstream emissions estimates from GREET are not used as they do not represent the vehicles or equipment used in the various pathway components. All upstream emissions assume a scenario year of 2020 and that the California electrical grid mix is the primary source of energy for stationary and transportation sector electricity consumption. Upstream emissions from hydrogen-fueled and electric vehicles use emission factors from California Air Resources Board's VISION model.

## ID #1-6: Short Range Drayage Trucks

### Primary data sources

Emissions data - California Air Resources Board EMFAC 2011
(http://www.arb.ca.gov/msei/modeling.htm#emfac2011_web_based_data)

### Basic Approach

EMFAC 2011 provides fleet emissions and activity for port trucks on a tons of pollutant/day and miles/day basis. These two metrics are used to convert emissions and fuel consumption to a grams of pollutant/mile and gallons/mile basis. Assuming a truck is transporting a single container of average weight (10.6 tons) results in an estimate of pollutant emissions in grams/ton-mile and fuel consumption in gallons/ton-mile. Upstream emissions are then calculated based on the calculated fuel consumption.

Emissions from EMFAC are based on aggregated vehicle speed data, annual average emissions rates, and a scenario year of 2020. Freight Component IDs 1-4a reflect EMFAC's assumed vehicle model year distributions for POLA/POLB and Port of Oakland. Freight Component IDs 4b, 5 and 6a are intended to reflect emissions from 2007 or 2010 compliant trucks and are limited to model year 2007 or 2010 trucks only. ID 6b is intended to reflect emissions from a truck meeting a future NOx standard that is 80% below the 2010 standard.

## ID #7-8: Regional Drayage Trucks

### Primary data sources

Emissions data - California Air Resources Board EMFAC 2011
(http://www.arb.ca.gov/msei/modeling.htm#emfac2011_web_based_data)

### Basic Approach

EMFAC 2011 provides fleet emissions and activity for Class 8 in-state trucks (category T7 in EMFAC) on a tons of pollutant/day and miles/day basis. These two metrics are used to convert emissions and fuel consumption to a grams of pollutant/mile and gallons/mile basis. Assuming a truck is transporting a single container of average weight (10.6 tons) results in an estimate of pollutant emissions in grams/ton-mile and fuel consumption in gallons/ton-mile. Upstream emissions are then calculated based on the calculated fuel consumption.

Emissions from EMFAC are based on aggregated vehicle speed data, annual average emissions rates, model years, and a scenario year of 2020.

## ID #9,11, & 12: Electric Short Range Drayage Truck

### Primary data sources

Fuel consumption data – Catenary Truck Market Study (GNA, 2012)

### Basic Approach

BEVs, PHEVs, and Catenary trucks are assumed to be operating entirely on electricity in near-dock operations and produce zero downstream emissions. Therefore, all emissions are associated with upstream production and distribution of the fuel. As in the Common Assumptions portion of this appendix, upstream emissions are calculated based on the fuel use per ton or ton-mile. Using an estimated 4 kw-hrs/mile for a battery electric truck and assuming a truck is transporting a single container of average weight (10.6 tons) results in an estimate of energy consumption in kw-hrs/ton-mile. Upstream emissions are then calculated using CARB's VISION model.

## ID #10: Fuel Cell Short Range Drayage Truck

### Primary data sources

Fuel consumption data – Catenary Truck Market Study (GNA, 2012)

### Basic Approach

FCVs are assumed to produce zero downstream emissions. Therefore, all emissions are associated with upstream production and distribution of the fuel. As in the Common Assumptions portion of this appendix, upstream emissions are calculated based on the fuel use per ton or ton-mile. Using an estimated 4.54 lbs of hydrogen per mile for a battery electric truck and assuming a truck is transporting a single container of average weight (10.6 tons) results in an estimate of energy consumption in lbs/ton-mile. Upstream emissions are then calculated as previously described using CARB's VISION model, assuming that 80% of hydrogen is produced via steam methane reformation at the fueling station and 20% is produced from renewable sources.

## ID #13: POLA/POLB Cargo Handling Equipment

### Primary data sources

Emissions data – Port of Long Beach 2011 emissions inventory
(http://www.polb.com/environment/air/emissions.asp)

ARB Cargo Handling Equipment 2011 emissions model
(http://arb.ca.gov/msei/categories.htm#offroad_motor_vehicles)

### Basic Approach

Cargo handling emissions are estimated on a grams/ton of cargo basis and reflect the emissions associated with moving a ton of cargo through a marine terminal, transitioning the cargo from one transportation mode to another (e.g. ship to truck, ship to rail, truck to ship, etc). The ports of Long Beach and Los Angeles are the only California ports known to publish detailed annual emissions inventories that allow the assessment of cargo handling emissions on a grams/ton basis. POLB reports emissions from CHE directly in grams/100,000 tonnes of cargo. Basic unit conversions allow reporting emissions in a grams/ton of cargo basis. The emissions inventory also reports CO2 emissions. These emissions are used to estimate fuel consumption rates based on GREET data for grams of CO2 per MMBTU of diesel fuel combusted. Upstream emissions are then calculated using GREET based on fuel consumption. Note that all port CHE activity is assumed to be equal to POLB emissions, regardless of the actual port.

2020 emissions are projected from the 2011 POLB emissions inventory by scaling down emissions and scaling up cargo throughput based on data from ARB's Cargo Handling Equipment 2011 emissions model. Total projected emissions and growth factors for calendar years 2020 and 2011 were compared to create scaling ratios. These ratios are then applied to the POLB emissions inventory to estimate cargo throughput and emissions for 2020.

## ID #14: Rail Yard Cargo Handling Equipment

### Primary data sources

Emissions data – ARB Cargo Handling Equipment 2011 emissions model
(http://arb.ca.gov/msei/categories.htm#offroad_motor_vehicles)

Rail yard activity data -http://www.arb.ca.gov/railyard/commitments/suppcomceqa070511.pdf

### Basic Approach

Cargo handling emissions for rail yards were calculated separately from port CHE and use emissions data in ARB's Cargo Handling Equipment emissions model. The model reports emissions on a calendar year basis. For the current modeling exercise, emissions from 2010 are used as this is the most current year that rail yard cargo activity is available. Calendar year 2020 emissions are projected by comparing emissions and activity estimates from the ARB Cargo Handling Equipment model to produce appropriate scaling factors, as described in ID#13. Estimated 2020 annual emissions from a rail yard are divided by the estimated 2020 annual cargo throughput for that rail yard to provide NOx and PM emissions in grams/ton of cargo. Cargo throughput data were only available for four rail yards listed in ARB's 2010 Rail Yard MOU. Estimated emissions rates are averaged across all four rail yards, weighted by cargo throughput, to provide composite emissions rates for NOx and PM. The ARB model does not provide CO2 or fuel consumption estimates. In lieu of these data, rail yard CHE is assumed to use the same amount of fuel per ton of cargo as port CHE. Upstream emissions are then calculated using GREET based on fuel consumption.

## ID #15: On-Dock Rail Activity

### Primary data sources

Emissions data – Port of Long Beach emissions inventory
(http://www.polb.com/environment/air/emissions.asp)

### Basic Approach

On-dock rail emissions were derived from the POLB emissions inventory. This inventory provides total annual emissions in tons per year. Additionally, estimated annual rail activity and associated cargo throughput are reported in trains/year and tons of cargo/train. Emissions data are further segregated into on-port and off-port activity as well as line haul and switcher locomotive sources. To estimate on-dock rail emissions, the total on-port emissions were divided by the total tons of rail-borne cargo per year, providing emissions estimates on a grams/ton of cargo basis. Note that these emissions represent emissions associated with train activity on the marine terminal as well as emissions associated with rail activity between the marine terminals and the near-dock rail yard (ICTF). Hence, this pathway component describes emissions for cargo originating at a marine terminal and ending at the near-dock rail facility five miles from the marine terminal and loaded on a freight train.

## ID #16: Tier 4 On-Dock Rail Activity

### Primary data sources

Emissions data – Port of Long Beach emissions inventory
(http://www.polb.com/environment/air/emissions.asp)

### Basic Approach

This pathway component estimates emissions associated with the same on-dock rail activity described in ID# 15, but assumes that all locomotives transitioned to Tier 4 emissions standards. Emissions estimates were produced by scaling the emissions identified in ID #15 by the percentage reductions in emissions required by Tier 4 standards relative to the emissions standards met by the current equipment. It is assumed that all existing line haul locomotives and off-dock switcher locomotives meet Tier 2 standards. Existing on-dock switcher locomotives are assumed to meet Tier 3 standards as this is reflective of the current fleet mix for PHL (the on-dock rail operator).

## ID #17: Tier 2 Rail Yard Switching

### Primary data sources

Emissions data – Port of Long Beach emissions inventory
(http://www.polb.com/environment/air/emissions.asp)

### Basic Approach

Emissions from rail yard switching locomotive activities were derived from the POLB emissions inventory. This inventory provides total annual emissions in tons per year. Additionally, estimated annual rail activity and associated cargo throughput are reported in trains/year and tons of cargo/train. Emissions data are further segregated into on-port and off-port activity as well as line haul and switcher locomotive sources. To estimate rail yard switching emissions, the off-port switcher locomotive emissions were divided by the total tons of rail-borne cargo per year, providing emissions estimates on a grams/ton of cargo basis. Note that these emissions inventories assume that the trains consist primarily of double-stacked container cars.

## ID #18: Tier 4 Rail Yard Switching

### Primary data sources

Emissions data – Port of Long Beach emissions inventory
(http://www.polb.com/environment/air/emissions.asp)

### Basic Approach

This pathway component estimates emissions associated with the same on-dock rail activity described in ID# 17, but assumes that all switcher locomotives transitioned to Tier 4 emissions standards. Emissions estimates were produced by scaling the emissions identified in ID #17 by the percentage reductions in emissions required by Tier 4 standards relative to the emissions standards met by the current equipment. It is assumed that all existing off-dock switcher locomotives meet Tier 2 standards.

## ID #19: Tier 2 Line Haul Rail

### Primary data sources

Emissions data – Port of Long Beach emissions inventory
(http://www.polb.com/environment/air/emissions.asp)

### Basic Approach

Emissions from line haul locomotive activities were derived from the POLB emissions inventory. This inventory provides total annual emissions in tons per year. Additionally, estimated annual rail activity and associated cargo throughput are reported in trains/year and tons of cargo/train. Emissions data are further segregated into on-port and off-port activity as well as line haul and switcher locomotive sources. To estimate line haul rail emissions, the off-port line haul locomotive emissions were divided by the total ton-miles of rail-borne cargo per year, providing emissions estimates on a grams/ton-mile of cargo basis. The annual ton-miles of rail-borne cargo was calculated by multiplying the total tonnage of rail-borne cargo travelling to/from the ports by the estimated distance the cargo travelled along the Alameda Corridor (21 miles) and between the Central LA and the Air Basin border (84) miles. These distances and geographic constraints were used because they reflect the geographic region considered in the emissions inventory. Note that these emissions inventories assume that the trains consist primarily of double-stacked container cars.

## ID #20: Tier 4 Line Haul Rail

### Primary data sources

Emissions data – Port of Long Beach emissions inventory
(http://www.polb.com/environment/air/emissions.asp)

### Basic Approach

This pathway component estimates emissions associated with the same on-dock rail activity described in ID# 19, but assumes that all line haul locomotives transitioned to Tier 4 emissions standards. Emissions estimates were produced by scaling the emissions identified in ID #19 by the percentage reductions in emissions required by Tier 4 standards relative to the emissions standards met by the current equipment. It is assumed that all existing line haul locomotives meet Tier 2 standards.

## ID #21: Electrified Line Haul Rail

### Primary data sources

Fuel consumption data – Estimated fuel consumption rates for diesel line haul locomotives in pathway component #19.

Diesel to electricity conversion assumptions – Cambridge Systematics report, "Analysis of Freight Rail Electrification in the SCAG Region" (2011)
http://freightworks.migcom.com/docManager/1000000129/Draft%20Freight%20Rail%20Electrification.pdf

### Basic Approach

Electric line haul locomotives are assumed to be operating entirely on electricity and produce zero downstream emissions. Therefore, all emissions are associated with upstream production and distribution of the fuel. As in the Common Assumptions portion of this appendix, upstream emissions are calculated based on the fuel use per ton-mile. The energy required at the wheels for electrified freight rail is assumed to be equivalent to diesel fuel consumption associated with Tier 2 line haul locomotives. Using estimated energy conversion efficiencies for electrified and diesel locomotives, provided by CamSys, the electrical energy demands from the grid were estimated and reported in kw-hrs/ton-mile. Upstream emissions are then calculated using CARB's VISION model.

## ID #22: Hybrid Tier 4 Rail Yard Switching

### Primary data sources

Baseline fuel consumption data – Estimated fuel consumption rates for diesel switcher locomotives in pathway component #17.

Fuel reduction benefits from hybrid technology – PHL demonstration report for the Green Goat hybrid switcher locomotive
(http://www.cleanairactionplan.org/civica/filebank/blobdload.asp?BlobID=2463)

### Basic Approach

Off-dock hybrid switcher locomotives are assumed to meet Tier 4 emissions requirements while achieving a 60% reduction in fuel consumption and CO2e emissions. This assumption, while possibly high, reflects benefits estimated by PHL from their demonstration of a hybrid switcher locomotive and manufacturer claims. Direct emissions of NOx and PM were assumed to be equal to the emissions identified in ID #18. CO2e emissions were assumed to be reduced by 60%. Upstream emissions are then calculated using GREET.

## ID #23: Electrified On-dock Rail Activity

### Primary data sources

Baseline fuel consumption data – Estimated fuel consumption rates for diesel locomotives in pathway components #19 and #22.

Diesel to electricity conversion assumptions – Cambridge Systematics report, "Analysis of Freight Rail Electrification in the SCAG Region" (2011)
http://freightworks.migcom.com/docManager/1000000129/Draft%20Freight%20Rail%20Electrification.pdf

### Basic Approach

Electrified on-dock rail activities are assumed to be operating entirely on electricity and produce zero downstream emissions. Therefore, all emissions are associated with upstream production and distribution of the fuel. As in the Common Assumptions portion of this appendix, upstream emissions are calculated based on the fuel use per ton of cargo. The energy required at the wheels for electrified freight rail is assumed to be equivalent to diesel fuel consumption associated with diesel locomotives, as given in pathway components #19 and #22 for on-dock activity. The fuel consumption associated with hybrid switcher locomotives (pathway component #22) was used in lieu of standard Tier 2 diesel switcher fuel consumption estimates to reflect fuel efficiency gains that would be anticipated from an electrified locomotive in a high idle application like locomotive switching. Fuel consumption from line haul locomotives is assumed to be equivalent to Tier 2 diesel locomotives (pathway component #19). Using estimated energy conversion efficiencies for electrified and diesel locomotives, provided by CamSys, the electrical energy demands from the grid were estimated and reported in kw-hrs/ton. Upstream emissions are then calculated using CARB's VISION model.

## ID #24: Electrified Rail Yard Switching

### Primary data sources

Baseline fuel consumption data – Estimated fuel consumption rates for hybrid diesel locomotives in pathway component #22.

Diesel to electricity conversion assumptions – Cambridge Systematics report, "Analysis of Freight Rail Electrification in the SCAG Region" (2011)
http://freightworks.migcom.com/docManager/1000000129/Draft%20Freight%20Rail%20Electrification.pdf

### Basic Approach

Electrified rail yard switching activities are assumed to be operating entirely on electricity and produce zero downstream emissions. Therefore, all emissions are associated with upstream production and distribution of the fuel. As in the Common Assumptions portion of this appendix, upstream emissions are calculated based on the fuel use per ton of cargo. The energy required at the wheels for electrified freight rail is assumed to be equivalent to diesel fuel consumption associated with hybrid diesel locomotives, as given in pathway component #22 for off-dock switching. The fuel consumption associated with hybrid switcher locomotives (pathway component #22) was used in lieu of standard Tier 2 diesel switcher fuel consumption estimates to reflect fuel efficiency gains that would be anticipated from an electrified locomotive in a high idle application like locomotive switching. Using estimated energy conversion efficiencies for electrified and diesel locomotives, provided by CamSys, the electrical energy demands from the grid were estimated and reported in kw-hrs/ton. Upstream emissions are then calculated using CARB's VISION model.

## ID #25: Electrified Freight Shuttle

### Primary data sources

Baseline fuel consumption data – Estimated fuel consumption rates for hybrid diesel locomotives in pathway component #21.

### Basic Approach

Electrified freight shuttles are assumed to be equivalent in energy consumption to electrified line haul rail as described in pathway component #21. As both technologies produce zero downstream emissions and are assumed to have the same energy consumption, the emissions from electrified freight shuttles are equal to electrified line haul rail.

## ID #26: On-Dock Rail Activity with Tier 4 Hybrid Switcher

### Primary data sources

Emissions data – Port of Long Beach emissions inventory (http://www.polb.com/environment/air/emissions.asp)

Fuel consumption and emissions estimates from pathway component #22 (hybrid switcher locomotive)

### Basic Approach

This pathway component estimates emissions associated with the same on-dock rail activity described in ID# 15, but assumes that all switcher locomotives transitioned to hybrid locomotives meeting Tier 4 emissions standards. Emissions estimates were produced by combining the emissions identified in ID #15 for Tier 2 line haul locomotives with the emissions identified in ID #22 for hybrid switcher locomotives.

## ID #27: Hybrid Tier 4 Line Haul Locomotive

This pathway was not considered as there is no known data for such a technology. Further, hybridization has the greatest potential benefits when applied to high idle operations such as switcher operations. Benefits decline quickly as vehicle operations become less transient, as would be expected in line haul operations.

## ID #28 & 29: Natural Gas Tier 4 Line Haul and Switcher Locomotives

### Primary data sources

Emissions data – Port of Long Beach emissions inventory (http://www.polb.com/environment/air/emissions.asp)

Estimated emissions from pathway components #18 and #20.

### Basic Approach

Downstream NOx and PM emissions estimates for Tier 4 natural gas switcher and line haul locomotives are identical to ID #18 and #20 (Tier 4 diesel switcher and line haul locomotives), respectively. Downstream CO2e emissions are corrected to account for the lower carbon intensity (in grams CO2/mmBTU of fuel) of natural gas as compared to diesel fuel. Upstream emissions are calculated in GREET for liquefied natural gas as the vehicle fuel.

## ID #30: Virtual Container Yards

### Primary data sources

Trip reduction estimates – Rutgers University Study "Investigating the Feasibility of Establishing a Virtual Container Yard to Optimize Empty Container Movement in the NY-NJ Region" (2007) (http://www.utrc2.org/sites/default/files/pubs/Investigating-Feasibility-of-Establishing-Virtual-Container-Yard.pdf)

METRANS Study "The Logistics of Empty Cargo Containers in the Southern California Region" (2003)
(http://www.metrans.org/research/final/01-05_Final.pdf)

### Basic Approach

The application of virtual container yards (VCY) and resulting benefits is highly specific to a given region and only rough approximations of the associated benefits can be made. Further, because emissions benefits are associated with reductions in trips of unloaded trucks, the benefits of VCYs are not well characterized on a grams/ton or grams/ton-mile of cargo basis. Two studies were identified that indicated similar ranges of VMT reduction – approximately 5% VMT reduction across a region's drayage fleet. Therefore, VCYs are assumed to provide a fixed 5% VMT reduction that is equated to a 5% reduction in emissions across a drayage truck fleet.

## ID #31a and 31b: Short Sea Shipping

### Primary data sources

Fuel-based emissions factors – Texas Transportation Institute study for MARAD "A Modal Comparison of Domestic Freight Transportation Effects on the General Public 2001-2009" (2012)
(http://www.nationalwaterwaysfoundation.org/study/FinalReportTTI.pdf)
US EPA, "Emissions Factors for Locomotives" (2009)
(http://www.epa.gov/nonroad/locomotv/420f09025.pdf)

### Basic Approach

Little data is available on marine emissions factors per ton-mile of cargo transported. One of the few commonly cited sources for such estimates is a study by the Texas Transportation Institute. This study used fuel-based factors to estimate the downstream emissions for an inland waterway towing vessel. Downstream emissions factors for marine vessels are derived from EPA's locomotive emissions factors as engines of the sizes considered in the report are both captured under the same emissions regulations and use essentially the same engines. CO2e emissions are used to calculate fuel consumption rates based on a reported factor of 98.97 diesel gallons/ton of CO2e. Upstream emissions are calculated using GREET values for non-road diesel fuel.

ID 31a reflects emissions from a Tier 2 compliant marine engine and ID 31b reflects emissions from a Tier 4 compliant marine engine.

## ID #32-34: Truck on Flatbed Car – Line haul and Switcher Locomotives

### Primary data sources

Emissions data – Port of Long Beach emissions inventory
(http://www.polb.com/environment/air/emissions.asp)

### Basic Approach

This pathway component estimates emissions associated with rail activity to move semi-tractors with trailers on flat bed rail cars. Both Tier 2 and Tier 4 emissions estimates follow the same approach as described in components #17-#20. Specifically, Tier 2 emissions are derived from annual POLB emissions inventory data. Tier 4 emissions estimates are produced by scaling the Tier 2 emissions estimates by the percentage reductions in emissions required by Tier 4 standards relative to the Tier 2 standards.

The emissions estimates for truck on flatbed railcars differ from the trains of double-stacked container cars reported in the POLB inventory. Trucks on flatbed railcars cannot be double stacked and have significant additional weight associated with the truck and trailer chassis that contribute to the gross train weight and limit the amount of cargo being transported by a single train. To account for these weight impacts, the weight of the truck and chassis are estimated at 24,000 lbs and one rail car per truck is required. Using the same gross train weight reported in the POLB emissions inventory, the tonnage of cargo per train is calculated. The per-train cargo throughput is multiplied by the number of trains per year to produce an annual cargo throughput estimate and used to report emissions on a grams/ton or grams/ton-mile basis. Fuel consumption is estimated based on CO2e emissions. Upstream emissions are then calculated using GREET and based on low sulfur diesel fuel.