Responses from the Oregon Global Warming Commission to Senate Environment and Natural Resources Committee questions

Committee meeting date: February 3, 2017

Q: Did the TriMet biodiesel issue have any effect on how accurate the state's GHG inventory is for transportation?

A: Fuel suppliers who bring fuel into Oregon are the entities that report to Oregon DEQ on the quantities that they are supplying. TriMet is not a reporting entity to DEQ for purposes of calculating the state's GHG inventory. Thus it is unlikely that this issue would have had any impact on the GHG emissions shown in the inventory.

To put this issue in the context of our total statewide GHG emissions, 5% of TriMet's 2015 diesel use (approximately reflecting a shift from 10% biodiesel to 5% biodiesel usage) represents 0.0043% of 2015 statewide emissions.

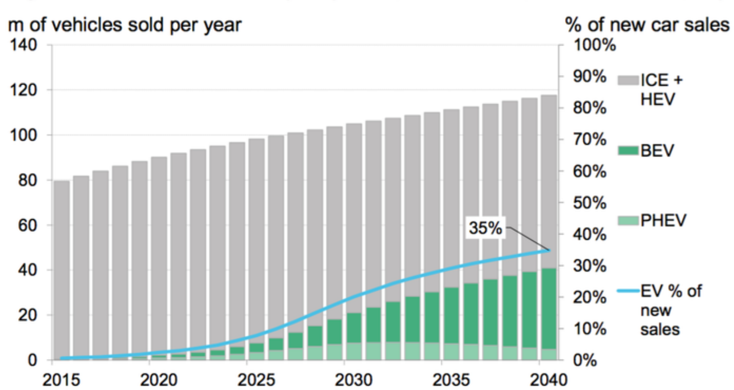
Q: What percent of EVs are we assuming will be adopted in the future?

A: First, the ODOT-sponsored Sustainable Transportation Strategy (STS) projected that to meet Oregon's GHG reduction goals, EV's would need to be >50% of the total light duty vehicle (LDV) fleet by that date (and new LDV sales would be near 90% by then).

How realistic is that?

Bloomberg New Energy Finance (2016) projects EV per cent of total vehicle sales will likely be around 35% of global sales by 2040. While that's substantially beneath the 90% of sales by 2050 figure, its also a global projection. Wealthier countries (the US) and early adopter areas (Oregon) can be expected to be significantly in advance of the larger sample. State incentives, such as those proposed in the 2017 session, can accelerate the curve.

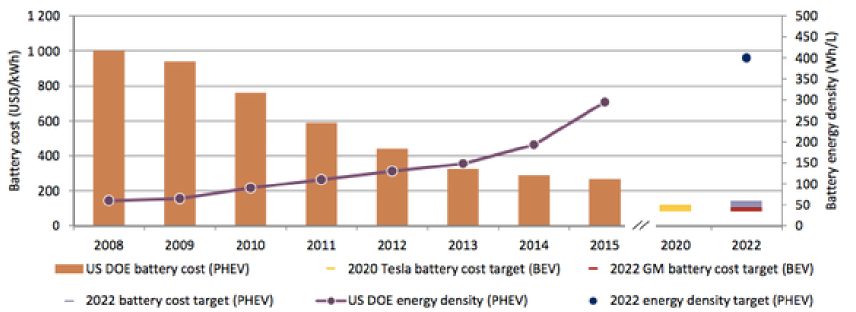
Figure 1: Global LDV and EV yearly sales, 2015 – 2040 (m vehicles sold per year, %)



Source: Bloomberg New Energy Finance Note: ICE+HEV = internal combustion engine and hybrid vehicles, BEV = battery electric vehicles, PHEV = plug-in hybrid electric vehicles.

To get to the target, battery costs have to come down (to around $125/kWh) and battery "density" (e.g., how far the vehicle will travel on a single charge) has to improve (to >200 mile range). Both trends are beating projections of just a few years ago.

Figure 2 • Evolution of battery energy density and cost



Notes: USD/kWh = United States dollars per kilowatt-hour; Wh/L = watt-hours per litre. PHEV battery cost and energy density data shown here are based on an observed industry-wide trend, include useful energy only, refer to battery packs and suppose an annual battery production of 100 000 units for each manufacturer.

Sources: US DOE (2015 and 2016) for PHEV battery cost and energy density estimates; EV Obsession (2015); and HybridCARS (2015).

Both the Chevy Bolt (available) and the Tesla Model 3 (soon available) beat the 200 mile range market, and report battery costs of around $150/kWh, below the USDOE projection shown above. A >300 mile range vehicle is expected to be introduced soon.

Level 2 and Level 3 recharging stations (including at home) will mean a full recharge (from zero to 200 mile range) may soon be available in under an hour.
And the Bolt is being listed in OR and CA for under $30,000, making it affordable to a broad spectrum of car buyers.

A last observation: new technologies tend to dawdle at low numbers for an extended time until technology fixes, costs and market conditions all intersect to allow takeoff and takeover. The takeoff curve has gotten progressively steeper as markets enable uptake; consider the telephone (35 years to 80%), to television (10 years), to smartphones (5 years). EV's are higher cost than these other technologies, and that will slow down the market penetration; but once they are first-cost-competitive with gasoline and diesel vehicles, their lower operating costs (fuel and servicing) should accelerate their curve to something like current auto turnover time(10 to 12 years).

Q: Where do we rank in the US for carbon emissions per capita?
A: This is a tricky question to answer because not all states compile GHG inventories, and those that do don't always use the same methodology as Oregon (namely, not all states account for the emissions associated with serving electric loads within their borders). According to the US EPA and US Census Bureau, nationwide per capita emissions were 21.5 metric tons in 2014. We calculated Oregon's per capita emissions to be 15.8 metric tons.

Q: How do Uber and Lyft help reduce emissions?
A: Two ways:

1. Rideshare services reduce the total number of vehicles operating on the roads, because travelers share those vehicles instead of each driving his or her own car. Fewer vehicles (even if those vehicles rack up more miles/car) mean less congestion, therefore more miles traveled per pound of CO_2 emitted.
2. More importantly, because the rideshare vehicles put on miles faster than do personal vehicles (which sit unused $\geq$ 90% of the time), they wear out faster, and are turned over by their owners faster. Each turnover is likely to be from a less-efficient vehicle to a more efficient one, as

drivers seek to increase their net earnings by reducing their cost per mile. And this is easy to do since auto manufacturers will be bringing out more efficient vehicles each year to meet this demand (and already are doing so).

Q: How much GHG reduction is expected from the clean fuels program?

A: Oregon DEQ is currently awaiting some new analysis from ICF on this question. Updates so far show that the program is expected to reduce 8.4 million metric tons over the 10 years of the program (versus a business-as-usual baseline). More information can be found here: http://www.deq.state.or.us/aq/cleanFuel/docs/itemBm3012717.pdf

Q: Is it possible to measure the carbon stored in different types of trees (age, species, etc)?

A: Yes, the Forest Service has a detailed methodology for measuring and then calculating the carbon stored in the various pools within the forest, based on different parameters such as age and species. A detailed description of the calculation methodology is attached as a PDF.

Q: How can we analyze the "costs to Oregonians" of GHG reduction policies, not just the "overall costs"?

A: There is plenty of anecdotal evidence that certain measures for reducing GHG emissions also save consumers and taxpayers substantial amounts of money. Energy efficiency measures generally save consumers money (most marginal abatement cost analyses done to-date have shown that there are significant negative-cost energy efficiency savings that could be achieved, see McKinsey & Company for one). The agreement to close Boardman early saved PGE ratepayers roughly $450mm in avoided pollution control costs. Electric vehicles generally still have a higher up-front cost than do internal combustion vehicles, but are becoming increasingly first-cost competitive (see above) while also giving buyers substantially lower operating costs. Of course there are other measures and technologies where the lower carbon options are more costly (residential solar panels, for example; although these costs are also dropping rapidly). That said, the OGWC agrees that the cost-effectiveness of different emissions reduction technologies and choices is an area that needs more rigorous analysis in Oregon, which we believe is an important reason for the Commission to have the staffing and budget needed to take on these more complex projects.

Appendix J. Biomass Estimation in the FIADB

In previous versions of the FIADB, a variety of regional methods were used to estimate tree biomass for live and dead trees in the TREE table. In FIADB 4.0, a new nationally consistent method of estimating tree biomass has been implemented. This new approach, called the component ratio method (CRM) (Heath and others 2009), involves calculating the dry weight of individual components before estimating the total aboveground or belowground biomass. The CRM approach is based on:

- converting the sound volume of wood (VOLCFSND) in the merchantable bole to biomass using a compiled set of wood specific gravities (Miles and Smith 2009) (see REF_SPECIES table for values)
- calculating the biomass of bark on the merchantable bole using a compiled set of percent bark estimates and bark specific gravities (Miles and Smith 2009) (see REF_SPECIES table for values)
- calculating the biomass of the entire tree (total aboveground biomass), merchantable bole outside bark, and belowground biomass using equations from Jenkins and others (2003)
- calculating the volume of the stump (wood and bark) based on equations in Raile (1982) and converting this to biomass using the same specific gravities used for the bole wood and bark
- calculating the top biomass (tree tip and all branches) by subtracting all other biomass components from the total aboveground estimate
- calculating an adjustment factor by developing a ratio between bole biomass from VOLCFSND to bole biomass from Jenkins and others (2003)
- applying the adjustment factor to all tree components derived from both Jenkins and Raile

The CRM approach is based on assumptions that the definition of merchantable bole in the volume prediction equations is equivalent to the bole (stem wood) in Jenkins and others (2003), and that the component ratios accurately apply.

The tables in this appendix describe the equations used in FIADB 4.0 to estimate components of tree biomass, including stem wood (bole), top and branches combined, bark, stump, and coarse roots. Most of these components are estimated through a series of ratio equations as described by Jenkins and others (2003). Stem wood biomass is calculated directly from the sound cubic-foot volume of the tree bole, percentage of bark on the bole, and specific gravities of both wood and bark.

Note that component equations are not available for woodland tree species or for saplings because saplings have no volume in FIADB. Because of this, only total aboveground biomass is estimated for saplings (trees from 1 to 4.9 inches in diameter) and woodland species [trees where diameter is measured at the root collar (DRC)]. The individual component biomass values for bole, top, and stump are not available in FIADB. Volume equations for woodland species include all wood and bark from ground to tip. When converted to biomass, the result is total aboveground biomass excluding foliage for these species. Belowground biomass is estimated for all trees greater than or equal to 1 inch.

Definitions of each biomass component and the equations used to estimate the ovendry weight in pounds are shown in appendix tables J-1 through J-5.

- Appendix table J-1 defines the columns that are stored in the TREE table, and clarifies the set of trees (species, dimensions, live or dead, etc) that are used in each calculation.

- Appendix table J-2 defines the Jenkins component equations and explains how the equation results are used to estimate biomass. The 'Estimate name' in this table is the same name found in the coefficient definitions described in the biomass-related columns 38 to 49 of the REF_SPECIES table.

- Appendix table J-3 contains the Jenkins equations used to estimate each biomass component. The equations use the exact coefficient column names found in the REF_SPECIES table (for example, JENKINS_TOTAL_B1 in appendix table J-3 is the column name in REF_SPECIES that holds the value of the coefficient needed in the total aboveground biomass equation). The Jenkins equations use the measured tree diameter to produce an estimate.

- Appendix table J-4 contains the actual equations used in the FIADB to estimate the biomass components stored in the TREE table. These equations are a blend of Jenkins ratios, calculated bole biomass (based on calculated volume from the TREE table), and adjustment factors. The adjustment factor is an important step because it relates measurement-based bole biomass (DRYBIO_BOLE) to generalized equation-based bole biomass to improve or adjust the computed results of the Jenkins equations.

- Appendix table J-5 contains equations that show the approach described by Heath and others (2009), where the proportion of the biomass component relative to stem volume is calculated first, and then is applied to DRYBIO_BOLE to develop the final estimate in pounds.

For more information please consult the publication by Heath and others (2009), titled *Investigation into calculating tree biomass and carbon in the FIADB using a biomass expansion factor approach*.

Appendix table J-1. Definition of Biomass Components stored in the TREE table

Component	**Column name**	**Biomass Component Definition** **(all are ovendry biomass, pounds)**
Merchantable stem (bole)	DRYBIO_BOLE	Merchantable bole of the tree, includes stem wood and bark, from a 1-foot stump to a 4-inch top diameter outside bark (DOB). Based on VOLCFSND and specific gravity for the species. For timber species with a DIA $\geq$ 5 inches DBH. Includes live and dead trees. (note that VOLCFGRS or VOLCFNET might be used after adjustment based on national averages, if VOLCFSND is not available)
Top	DRYBIO_TOP	Top of the tree above 4 inches DOB and all branches; includes wood and bark and excludes foliage. For timber species with a DIA $\geq$ 5 inches DBH. Includes live and dead trees.
Stump	DRYBIO_STUMP	Stump of the tree, the portion of a tree bole from ground to 1 foot high, includes wood and bark. For timber species with a DIA $\geq$ 5 inches DBH. Includes live and dead trees.
Belowground	DRYBIO_BG	Coarse roots of trees and saplings with a DIA $\geq$ 1 inch DBH or DRC. Includes timber and woodland species, and live and dead trees.
Saplings	DRYBIO_SAPLING	Total aboveground portion of live trees, excluding foliage. For timber species with a DIA $\geq$ 1 inch and less than 5 inches DBH.
Woodland tree species	DRYBIO_WDLD_SPP	Total aboveground portion of tree, excluding foliage. For woodland species with a DIA $\geq$ 1 inch DRC. Includes live and dead trees. Woodland species can be identified by REF_SPECIES.WOODLAND = X, TREE.DIAHTCD = 2, or TREE.WDLDSTEM > 0

Appendix table J-2. Jenkins Biomass Component Equation Definitions
(Refer to the REF_SPECIES table for equation coefficients and adjustment factors)

Component	**Estimate name**	**Definition**
Total aboveground biomass	total_AG_biomass_ Jenkins	Total biomass of the aboveground portion of a tree. Includes stem wood, stump, bark, top, branches, and foliage. (ovendry biomass, pounds)
Stem wood biomass ratio	stem_ratio	A ratio that estimates biomass of the merchantable bole of the tree, by applying the ratio to total_AG_biomass_Jenkins. Includes wood only. This is the portion of the tree from a 1-foot stump to a 4-inch top DOB.
Stem bark biomass ratio	bark_ratio	A ratio that estimates biomass of the bark on the merchantable bole of the tree, by applying the ratio to total_AG_biomass_Jenkins.
Foliage biomass ratio	foliage_ratio	A ratio that estimates biomass of the foliage on the entire tree, by applying the ratio to total_AG_biomass_Jenkins.
Coarse root biomass ratio	root_ratio	A ratio that estimates biomass of the belowground portion of the tree, by applying the ratio to total_AG_biomass_Jenkins.
Stump biomass	stump_biomass	An estimate of the stump biomass of a tree, from the ground to 1 foot high. Uses a series of equations that estimate first the diameter inside and outside bark, followed by volume inside and outside bark developed by Raile (1982). Wood and bark volumes are converted to biomass using specific gravity for the species.
Sapling biomass adjustment	JENKINS_SAPLING _ADJUSTMENT	An adjustment factor that is used to estimate sapling biomass for the tree, by applying the factor to the total aboveground estimate excluding foliage. The adjustment factor was computed as a national average ratio of the DRYBIOT (total dry biomass) divided by the Jenkins total biomass for all 5.0-inch trees, which is the size at which biomass based on volume begins.

Appendix table J-3. Jenkins Biomass Equations (Actual B1 and B2 coefficients and adjustment factors are stored in the REF_SPECIES table.) Note: these equations are used in appendix table J-4 to estimate the biomass components stored in the TREE table.

Component	**Equation**
total_AG_biomass_Jenkins (pounds) (total aboveground biomass, includes wood and bark for stump, bole, top, branches, and foliage)	= exp(JENKINS_TOTAL_B1 + JENKINS_TOTAL_B2 * ln(DIA*2.54)) * 2.2046
stem_ratio	= exp(JENKINS_STEM_WOOD_RATIO_B1 + JENKINS_STEM_WOOD_RATIO_B2 / (DIA*2.54))
bark_ratio	= exp(JENKINS_STEM_BARK_RATIO_B1 + JENKINS_STEM_BARK_RATIO_B2 / (DIA*2.54))
foliage_ratio	= exp(JENKINS_FOLIAGE_RATIO_B1 + JENKINS_FOLIAGE_RATIO_B2 / (DIA*2.54))
root_ratio	= exp(JENKINS_ROOT_RATIO_B1 + JENKINS_ROOT_RATIO_B2 / (DIA*2.54))
stem_biomass_Jenkins (pounds)	= total_AG_biomass_Jenkins * stem_ratio
bark_biomass_Jenkins (pounds)	= total_AG_biomass_Jenkins * bark_ratio
bole_biomass_Jenkins (pounds)	= stem_biomass_Jenkins + bark_ biomass_Jenkins
foliage_biomass_Jenkins (pounds)	= total_AG_biomass_Jenkins * foliage_ratio
root_biomass_Jenkins (pounds)	= total_AG_biomass_Jenkins * root_ratio
stump_biomass (pounds)	Volumes of wood and bark are based on diameter inside bark (DIB) and DOB equations from Raile, 1982. DIB = (DIA * RAILE_STUMP_DIB_B1) + (DIA * RAILE_STUMP_DIB_B2 * (4.5-HT) / (HT+1)) DOB = DIA + (DIA * RAILE_STUMP_DOB_B1 * (4.5-HT) / (HT+1)) Volume is estimated for 0.1ft (HT) slices from ground to 1 foot high (HT), and summed to compute stump volume. Bark_volume = Volume_outside_bark – Volume_inside_bark Bark and wood volumes are multiplied by their respective specific gravities and added together to estimate biomass
top biomass_Jenkins (pounds)	= total_AG_biomass_Jenkins – stem_biomass – bark_biomass – foliage_biomass – stump_biomass

Appendix table J-4. Equations used to calculate Biomass Components stored in the TREE table

Column name	**Equation (refer to Appendix J-3 for details on variables found in equations below)**
	AdjFac = DRYBIO_BOLE / bole_biomass_Jenkins **AdjFac_woodland** = DRYBIO_BOLE / (total_AG_biomass_Jenkins – foliage_biomass_Jenkins)
DRYBIO_BOLE (wood and bark) (see note below)	VOLUME = VOLCFSND (or VOLCFRS, VOLCFNET that are adjusted for the percent sound) = (VOLUME * (BARK_VOL_PCT/100.0) * (BARK_SPGR_GREENVOL_DRYWT * 62.4)) + (VOLUME * (WOOD_SPGR_GREENVOL_DRYWT * 62.4)) Note: For woodland species, volume equations produce volume outside bark, from ground to tip including branches, therefore DRYBIO_BOLE is the biomass from ground to tip. Wood and bark volumes need to be estimated before converting to biomass as follows: = (VOLUME * (BARK_VOL_PCT/100.0) * (BARK_SPGR_GREENVOL_DRYWT * 62.4)) + ((VOLUME – (VOLUME * (BARK_VOL_PCT/100.0))) * (WOOD_SPGR_GREENVOL_DRYWT * 62.4))
DRYBIO_TOP	= top_biomass_Jenkins * **AdjFac**
DRYBIO_STUMP	= stump_biomass * **AdjFac**
DRYBIO_SAPLING	= (total_AG_biomass_Jenkins – foliage_biomass_Jenkins) * JENKINS_SAPLING_ADJUSTMENT
DRYBIO_WDLD_SPP	= DRYBIO_BOLE (trees>= 5 inches DIA_) = DRYBIO_SAPLING (trees < 5 inches DIA) For tree species where REF_SPECIES.WOODLAND = X, TREE.DIAHTCD = 2, and/or TREE.WDLDSTEM > 0 Note: volume equations produce volume from ground to tip, including branches; DRYBIO_BOLE is the biomass of all wood from ground to tip
DRYBIO_BG	= root_biomass_Jenkins * **AdjFac** (for timber spp >= 5 inches DIA) = root_biomass_Jenkins * **AdjFac_woodland** (for woodland spp >= 5 inches DIA) = root_biomass_Jenkins * JENKINS_SAPLING_ADJUSTMENT (for all trees < 5 inches DIA)

Note:
If DIA >= 5.0 and VOLCFSND > 0 then VOLUME = VOLCFSND
If DIA >= 5.0 and VOLCFSND = (0 or null) and VOLCFGRS > 0 then VOLUME = VOLCFGRS * Percent Sound
If DIA >= 5.0 and VOLCFSND and VOLCFGRS = (0 or null) then VOLUME = VOLCFNET * (Ratio of cubic foot sound to cubic foot net vol)

Appendix table J-5. Alternative method to calculate Biomass Components, following Heath and others, 2009

Component	**Equation**
DRYBIO_BOLE (wood and bark)	VOLUME = VOLCFSND (or VOLCFRS, VOLCFNET that are adjusted for the percent sound) = (VOLUME * (BARK_VOL_PCT/100.0) * (BARK_SPGR_GREENVOL_DRYWT * 62.4)) + (VOLUME * (WOOD_SPGR_GREENVOL_DRYWT * 62.4))
TOP_proportion	= top_biomass_Jenkins / bole_biomass_ Jenkins
DRYBIO_TOP	= TOP_proportion * DRYBIO_BOLE
STUMP_proportion	= stump_biomass / bole_biomass_ Jenkins
DRYBIO_STUMP	= STUMP_proportion * DRYBIO_BOLE
BG_proportion	= root_biomass_Jenkins / bole_biomass_ Jenkins
DRYBIO_BG	= BG_proportion * DRYBIO_BOLE
BARK_proportion	= bark_biomass_Jenkins / bole_biomass_ Jenkins
DRYBIO_BARK	= BARK_proportion * DRYBIO_BOLE