NFRMPO
NORTH FRONT RANGE METROPOLITAN PLANNING ORGANIZATION

419 Canyon Avenue, Suite 300
Fort Collins, Colorado 80521
(970) 221-6243
FAX: (970) 416-2406
nfrmpo.org
www.VanGoVanpools.org

MEMORANDUM

To: NFRMPO Technical Advisory Committee

From: Medora Kealy

Date: October 17, 2018

Re: REVISED 2018 Call for Projects CMAQ Emissions Formulas

Background

Emissions formulas are needed to score Congestion Mitigation & Air Quality (CMAQ) projects during the 2018 Call for Projects. TAC discussed formulas for the 2018 Call for Projects in June and July 2018. This Action item was postponed until October 17, 2018 to allow time for the statewide workshop on CMAQ emissions formulas, which was convened by CDOT to promote consistency across the state due to federally required reporting and performance management targets for CMAQ emissions benefits.

The statewide workshop was held on October 9, 2018. At the workshop, staff from CDOT, the Denver Regional Council of Governments (DRCOG), the Federal Highway Administration (FHWA), the NFRMPO, the Regional Air Quality Council (RAQC), and the Upper Front Range (UFR) identified recommended CMAQ emissions formulas. The workshop attendees made their recommendations based on the tools that provided the most accurate and up-to-date estimate of benefits. The recommended tool varies by project type, reflecting the relative strengths of each tool.

On October 11, a TAC Work Session was held to discuss the results of the CDOT workshop and to prepare for the October 17 Action item. At the Work Session, TAC members requested example project calculations for new public transit operations and roundabouts and a table comparing emissions benefits across tools. Attendees emphasized the need to compare projects fairly (i.e. apples to apples). As all CMAQ emissions benefits are estimates, the role of assumed input datapoints was discussed. Attendees requested information on the two signal projects submitted in 2016, as they seemed similar but had substantially different emissions benefits. The information requested at the Work Session is included in the attachment.

In the most recent Call for Projects held in 2016, the NFRMPO used the Michigan DOT (MDOT) forms and the EPA's Diesel Emissions Quantifier (DEQ) to estimate emissions benefits. The DEQ was used for alternative fuel projects and the MDOT forms were used for all other project types. In recent years, a new FHWA-sponsored tool, the CMAQ Emissions Calculator Toolkit, has become available. As of August 2018, MDOT issued guidance to use the FHWA toolkit whenever possible and only use MDOT Forms when an FHWA tool is not available. The DEQ is not well-suited to analyzing the benefits of

alternative fuel projects as it does not have CNG-specific factors, and instead subs in diesel factors.

The first section of the attachment describes the tools discussed at the CDOT workshop. Recommended tools by project type are presented in **Table 1** as identified by MDOT, the CDOT Workshop attendees, and NFRMPO staff. Next, the attachment includes example emissions benefits calculations using the NFRMPO staff tool recommendations for the most common project types. **Table 2** presents the five-year emissions benefits calculated by different tools for the example projects. The last section of the attachment provides the emissions benefits calculated in 2016 for the *Greeley Central System and Controller Replacement* project and the *Loveland Traffic Signal Progression Improvements – US 34* project.

Action

Staff requests TAC determine which CMAQ emissions tools to use in the 2018 Call for Projects.

CDOT Workshop - Recommended Tools

CMAQ Emissions Calculator Toolkit – FHWA

- Developed by FHWA as an optional resource for DOTs, MPOs, and CMAQ project sponsors
- Currently provides six modules covering a variety of project types
- Since TAC last discussed emissions formulas in July, a new module has been added to the toolkit for Transit Bus and Fleet Expansion
- Additional modules are under development for Bicycle/Pedestrian Improvements and Diesel Idle Reduction Technologies for release in late 2018
- Emission rates are primarily based on a national-level run of the EPA MOVES2014a model
- https://www.fhwa.dot.gov/environment/air_quality/cmaq/toolkit/

GREET/AFLEET – Argonne National Laboratory

- Developed by Argonne Labs through funding from the Department of Energy
- County-specific for fuel profiles and upstream emissions
- Emissions factors are based on a combination of state-level EPA MOVES2014a data and operational analysis
- Updated annually with the most recent available data and studies
- AFLEET is a built tool that requires inputs and provides outputs
- GREET is the life-cycle assessment (LCA) model that allows for in-depth simulation parameter changes and provides operational and well-to-wheels (WTW) emission factors for vehicles
- https://greet.es.anl.gov/

TDM ROI Calculator – Mobility Lab

- Developed by Arlington County, VA, LDA consulting, and the University of South Florida with funding from USDOT
- Area-specific for traffic and density (choose from 103 metro areas)
- Users enter basic information about the TDM services they offer and the participation level of those services
- Loaded with data from more than 30 surveys from across the nation that users do not need to enter because it is embedded in the background of the tool
- Provides VMT reductions as well as return on investment for TDM and TCM projects
- Has some built-in calculations for emissions, but they are not area specific, offer few options and are not frequently updated
- https://mobilitylab.org/the-tdm-roi-calculator-and-manual/

Diesel Emissions Quantifier - EPA

- Developed by EPA
- Evaluates clean diesel projects and upgrade options for medium-heavy and heavy-heavy duty diesel engines
- Has some default values for fuel use and annual vehicle mileage
- https://cfpub.epa.gov/quantifier/index.cfm?action=main.home

CDOT Workshop - Not Recommended Tools

Michigan Department of Transportation (MDOT) Emissions Forms

- Developed by MDOT
- Currently provides seven forms covering a variety of project types
- As of August 2018, MDOT issued guidance[1] stating to use the FHWA Emission Calculator Toolkit whenever possible and only use MDOT Forms when an FHWA tool is not available
- https://www.michigan.gov/mdot/0,4616,7-151-9621_11041_60661---,00.html

[1] MDOT, Congestion Mitigation and Air Quality (CMAQ) FHWA Toolkit and Emissions Form Guidance, https://www.michigan.gov/documents/mdot/MDOT_CMAQEmissionFormsInstr_437269_7.pdf.

Table 1. Recommended Tools by Project Type

Project Type	MDOT Recommendation	CDOT Workshop Recommendation	Staff Recommendation
Dedicated turn lanes, signal interconnects, signal optimization or actuation, and roundabouts	FHWA Traffic Flow Improvements Tool	FHWA Traffic Flow Improvements Tool	FHWA Traffic Flow Improvements Tool
Non-Motorized Pathway	MDOT Form 2621	FHWA Bicycle/Pedestrian Improvements Tool *(to be released in late 2018)*	MDOT Form 2621
Intelligent Transportation System (ITS)	MDOT Form 2612	GREET/AFLEET	GREET/AFLEET
Travel Demand Management (TDM)	MDOT Form 2619	TDM ROI Calculator and GREET/AFLEET	TDM ROI Calculator and GREET/AFLEET
Park and Ride Lots	MDOT Form 2613	TDM ROI Calculator and GREET/AFLEET	TDM ROI Calculator and GREET/AFLEET
Carpooling, Vanpooling, and Rideshare	FHWA Carpooling and Vanpooling Tool	TDM ROI Calculator and GREET/AFLEET	TDM ROI Calculator and GREET/AFLEET
Operation of New Public Transit Services	MDOT form 2620 (for more than one route, use form 2620 for each route and sum the emission benefits in form 2608)	FHWA Transit Bus and Fleet Expansion	FHWA Transit Bus and Fleet Expansion
Bus Purchase or Replacements	FHWA Transit Bus Retrofits and Replacement Tool	GREET/AFLEET	GREET/AFLEET
Diesel Retrofits	FHWA Transit Bus Retrofits and Replacement Tool	EPA Diesel Emissions Quantifier	EPA Diesel Emissions Quantifier
Alternative Fuel Infrastructure and Vehicles	FHWA Alternative Fuels and Vehicles Tool	GREET/AFLEET	GREET/AFLEET
Idle Reduction	-	GREET/AFLEET	GREET/AFLEET

Example Calculations

Auxiliary Lane – FHWA Traffic Flow Improvements Tool

Inputs	Road 1	Road 2
AADT (both directions)	55,000	6,400
Peak Hour Volume (both directions)	4,500	600
Number of Lanes (one direction)	3	1
Truck Percentage	4%	1%
Existing Delay per Vehicle (sec/vehicle)	8	60
Existing Left-turn Phase	Yes	Yes
Existing Right-turn Phase	No	No
Number of Left-Turn Lanes to Add	1	1
Planned Left-turn Phase	Yes	Yes
Planned Right-turn Phase	No	No
Ratio of Green Time per Cycle Time	.7	.3

Cost: $1,025,000

Emission	Total Emissions Reduced (KG)	Cost Effectiveness (Cost per KG)
NOx	75	$13,697
VOC	31	$32,578

Signal Synchronization - FHWA Traffic Flow Improvements Tool

Inputs

- Area Type – Urban
- Corridor Length – 4 miles
- Number of signalized intersections – 12
- Number of Lanes – 3
- Speed Limit – 50 mph
- Average Speed – 31 mph
- Expected Increase in Speed – 5 mph
- Average Cycle Length – 110 seconds
- Truck Percentage – 6%
- AADT – 55,000
- Peak-Hour Volume – 6,000
- Existing Corridor Travel Time – 10 minutes
- Cost – $800,000

Emission	Total Emissions Reduced (KG)	Cost Effectiveness (Cost per KG)
NOx	1,801	$444
VOC	1,069	$748

Non-Motorized Pathway - MDOT Form 2621

Inputs

- Length – 0.75 miles
- ADT – 58,000
- Percentage of bike/ped – 3%
- Average speed on road – 43 mph
- Cost – $1,000,000

Emission	Total Emissions Reduced (KG)	Cost Effectiveness (Cost per KG)
NOx	317	$3,148
VOC	113	$8,818

Alternative Fuel Bus Replacement – GREET/AFLEET

Inputs

- Old Fuel Type – Diesel
- New Fuel Type – CNG
- Old Model Year – 2010
- New Model Year – 2020
- VMT – 26,250
- Cost – $600,000
- Annual Fuel Gallons – 3,269
- Annual Idling Hours – 600
- Cost - $600,000

Emission	Total Emissions Reduced (KG)	Cost Effectiveness (Cost per KG)
NOx	170	$3,510
VOC	1	$433,448

Diesel Engine Repower – EPA DEQ

Inputs

- Vehicle Type – Short Haul Single Unit Class 6-7
- Old Engine Year – 2010
- New Engine Year – 2020
- VMT – 14,962
- Annual Fuel Gallons –14,962
- Annual Idling Hours – 30
- Cost - $10,000

Emission	Total Emissions Reduced (KG)	Cost Effectiveness (Cost per KG)
NOx	36	$275
VOC	N/A	N/A

Operation of New Transit - FHWA Transit Bus and Fleet Expansion

Inputs

- Transit Bus miles traveled before – 0
- Transit bus miles traveled after – 109,200
- Passenger vehicle miles traveled before – 0
- Passenger vehicle miles traveled after – 3,026,400
- Time aggregation – Annual
- Days operated per year - 260
- Cost - $525,000

Emission	Total Emissions Reduced (KG)	Cost Effectiveness (Cost per KG)
NOx	13,040	$73
VOC	4,450	$214

Roundabout – FHWA Traffic Flow Improvement Tool

Inputs	Road 1	Road 2
AADT (both directions)	10,450	3,000
Peak Hour Volume (both directions)	1,045	300
Number of Lanes (one direction)	1	1
Truck Percentage	4%	4%
Existing Delay per Vehicle (sec/vehicle)	4	4
Existing % Left Turns	15%	15%
Existing % Right Turns	10%	10%
Area Type	Urban	
Existing intersection is	Unsignalized	
Number of circulating roundabout lanes	1	
Cost	$750,000	

Emission	Total Emissions Reduced (KG)	Cost Effectiveness (Cost per KG)
NOx	144	$5,209
VOC	43	$17,297

Table 2. Five-Year Emissions Benefits by Tool for Example Projects (NOx / VOC)

Project Type	MDOT	EPA DEQ	FHWA Toolkit	GREET/ AFLEET
Auxiliary Lane	N/A	N/A	75 /31	N/A
Signal Synchronization	660 / 3,564	N/A	1,801 / 1,069	N/A
Non-Motorized Pathway	317 / 113	N/A	N/A	N/A
CNG Bus Replacement	N/A	113 / N/A *diesel factor	27 / -1	170 / 1
Diesel Engine Repower	N/A	36 / N/A	127 / 2	N/A
Operation of New Public Transit	59,997 / 4,804	N/A	13,040 / 4,450	N/A
Roundabout	N/A	N/A	144 / 43	N/A

TRAFFIC SIGNAL INTERCONNECTION, MODERNIZATION AND/OR OPTIMIZATION

Project Name: Traffic Signal Progression Improvements--US 34

Submitter: Dave W. Klockman

EMISSION CALCULATIONS

Line No.	Description of Data Item/Formula	VOC	NOx
1	Number of miles of arterials affected (miles)	8	8
2	24-hour, 2-way traffic volume: (vehicles a day)	60,000	60,000
3	Percent of travel in peak periods (cannot exceed 1)	0.1	0.1
4	Peak period VMT = L1*L2*L3 (miles)(day)	48,000	48,000
5	Off-peak period VMT = L1*L2*(1-L3) (miles)(day)	432,000	432,000
6	BEFORE IMPLEMENTATION: Average peak travel speed (mph)	31	31
7	BEFORE IMPLEMENTATION: Average off-peak travel speed (mph)	44	44
8	Expected increase in peak period speed (mph)	2	2
9	Expected increase in off-peak period speed (mph)	4	4
10	AFTER IMPLEMENTATION: Average peak speed (mph) = L6+L8	33	33
11	AFTER IMPLEMENTATION: Average off-peak speed (mph) = L7+L9	48	48
12	BEFORE IMPLEMENTATION: Peak emission factor for speed on L6 (g/mi)	2.723873759	0.572117333
13	AFTER IMPLEMENTATION: Peak emission factor for speed on line 10 (g/mi)	2.581314199	0.546182147
14	Change in peak emission factor=L13-L12 (g/mi)	-0.14255956	-0.02593519
15	BEFORE IMPLEMENTATION: Off-peak emission factor for speed on line 7 (g/mi)	2.3698237390	0.465537844
16	AFTER IMPLEMENTATION: Off-peak emission factor for speed on line 11 (g/mi)	2.331865449	0.443680146
17	Change in off-peak emission factor=L16-L15 (g/mi)	-0.038	-0.022
18	Peak daily emissions reduced=L4*L14 (g/day)	-6,842.86	-1,244.89
19	Off-peak daily emissions reduced=L5*L17 (g/day)	-16,397.98	-9,442.53
20	Total change in emissions=L18+L19 (g/day) [(-)=Reduction; (+)=Increase]	-23,240.84	-10,687.41
21	Comparative purpose only: Convert to Tons/Year =L22*0.0011Tons/Kg (Tons/Yr)	-6.136	-2.821
22	Annual change in emissions=L23*240days (Kg/Yr)	-5,577.80	-2,564.98
23	Change in emissions=[(L20)/(1Kg/1000g))] (Kg/day)	**-23.24**	**-10.69**

COST-BENEFIT ANALYSIS

24	Project for 5 years	5	5
25	Total Federal Cost	$800,000	$800,000
26	Emission change over five years of the project=L23*L24 (Tons/5 years)	-30.68	-14.11
27	Emission change five years of the project=(L22*340)*L24 (Kg/5 years)	-27,889.0	-12,824.9
28	Cost per Ton over 5 years of the project=(L25/L26) ($/Tons/5 years)	$26,077.40	$56,707.88
29	Cost per Kilogram over 5 years of the project=(L25/L27) ($/Kg/5 Yrs)	**$28.69**	**$62.38**

SUMMARY

30	Short Term Emissions (1 Year)	**-5,577.80**	**-2,564.98**
31	Long Term Emissions (2-5 Years)	**-22,311.21**	**-10,259.92**
32	Total Cost per Kilogram over 5 years	**$28.69**	**$62.38**

TRAFFIC SIGNAL INTERCONNECTION, MODERNIZATION AND/OR OPTIMIZATION

Project Name: Central System and Controller Replacement

Submitter: Eric Bracke

EMISSION CALCULATIONS

Line No.	Description of Data Item/Formula	VOC	NOx
1	Number of miles of arterials affected (miles)	57.00	57.00
2	24-hour, 2-way traffic volume: (vehicles a day)	2,575,016.00	2,575,016.00
3	Percent of travel in peak periods (cannot exceed 1)	0.095	0.095
4	Peak period VMT = L1*L2*L3 (miles)(day)	13,943,711.64	13,943,711.64
5	Off-peak period VMT = L1*L2*(1-L3) (miles)(day)	132,832,200.36	132,832,200.36
6	BEFORE IMPLEMENTATION: Average peak travel speed (mph)	34	34
7	BEFORE IMPLEMENTATION: Average off-peak travel speed (mph)	36	36
8	Expected increase in peak period speed (mph)	2	2
9	Expected increase in off-peak period speed (mph)	2	2
10	AFTER IMPLEMENTATION: Average peak speed (mph) = L6+L8	36	36
11	AFTER IMPLEMENTATION: Average off-peak speed (mph) = L7+L9	38	38
12	BEFORE IMPLEMENTATION: Peak emission factor for speed on L6 (g/mi)	2.522324036	0.533214554
13	AFTER IMPLEMENTATION: Peak emission factor for speed on line 10 (g/mi)	2.467708412	0.517683261
14	Change in peak emission factor=L13-L12 (g/mi)	-0.054615624	-0.015531293
15	BEFORE IMPLEMENTATION: Off-peak emission factor for speed on line 7 (g/mi)	2.4677084120	0.517683261
16	AFTER IMPLEMENTATION: Off-peak emission factor for speed on line 11 (g/mi)	2.437130715	0.501440783
17	Change in off-peak emission factor=L16-L15 (g/mi)	-0.031	-0.016
18	Peak daily emissions reduced=L4*L14 (g/day)	-761,544.512	-216,563.871
19	Off-peak daily emissions reduced=L5*L17 (g/day)	-4,061,702.774	-2,157,524.092
20	Total change in emissions=L18+L19 (g/day) [(-)=Reduction; (+)=Increase]	-4,823,247.287	-2,374,087.963
21	Comparative purpose only: Convert to Tons/Year =L22*0.0011Tons/Kg (Tons/Yr)	-1,273.337	-626.759
22	Annual change in emissions=L23*240days (Kg/Yr)	-1,157,579.349	-569,781.111
23	Change in emissions=[(L20)/(1Kg/1000g))] (Kg/day)	**-4,823.247**	**-2,374.088**

COST-BENEFIT ANALYSIS

24	Project for 5 years	5	5
25	Total Federal Cost	$525,000	$525,000
26	Emission change over five years of the project=L23*L24 (Tons/5 years)	-6,366.69	-3,133.80
27	Emission change five years of the project=(L22*340)*L24 (Kg/5 years)	-5,787,896.7	-2,848,905.6
28	Cost per Ton over 5 years of the project=(L25/L26) ($/Tons/5 years)	$82.46	$167.53
29	Cost per Kilogram over 5 years of the project=(L25/L27) ($/Kg/5 Yrs)	**$0.09**	**$0.18**

SUMMARY

30	Short Term Emissions (1 Year)	**-1,157,579.35**	**-569,781.11**
31	Long Term Emissions (2-5 Years)	**-4,630,317.40**	**-2,279,124.44**
32	Total Cost per Kilogram over 5 years	**$0.09**	**$0.18**