Appendix D
Technical Source Documentation for Emissions Calculations

Prepared for:
California Air Pollution Control Officers Association (CAPCOA)

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in collaboration with
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1 Overview

This appendix contains additional technical detail related to the quantification of some emission sources, as cross-referenced in the User Guide and Appendix C, *Emission Calculation Details for CalEEMod*. Much of the information is based on studies and analysis completed for prior versions of CalEEMod. The source date in the footer reflects the date the material was last revised.

Appendix D1 - Construction Survey by South Coast AQMD

South Coast AQMD performed some construction surveys in order to develop default equipment usage and construction phase lengths. The initial survey was for projects less than five acres in size and is described in the following reference: The Sample Construction Scenarios for Projects Less than Five Acres in Size (http://www.aqmd.gov/ceqa/handbook/LST/FinalReport.pdf)

An additional 16 sites between five and 30 acres were surveyed for mid-sized projects. The amount and types of equipment was developed by attempting to find trends in data (i.e., comparing projects within the same project size, length of construction phases, number of pieces of equipment with areas disturbed, etc.).

The results of these surveys are included in the following tables.

Appendix D1 - Construction Survey By South Coast AQMD

Demolition
One Acre

Equipment Type	No. of Equip	hr/day
Rubber Tired Dozers	1	1
Concrete/Industrial Saws	1	8
Excavators		
Bore/Drill Rigs		
Tractors/Loaders/Backhoes	2	6
	4	

Demolition
Two Acre

Equipment Type	No. of Equip	hr/day
Rubber Tired Dozers	1	8
Concrete Saw	1	8
Excavators		
Bore/Drill Rigs		
Tractors/Loaders/Backhoes	3	8
	5	

Demolition
Three Acre

Equipment Type	No. of Equip	hr/day
Rubber Tired Dozers	1	8
Concrete Saw	1	8
Excavators		
Bore/Drill Rigs		
Tractors/Loaders/Backhoes	3	8
	5	

Demolition
Five Acre

Equipment Type	No. of Equip	hr/day
Rubber Tired Dozers	2	8
Concrete Saw	1	8
Excavators	3	8
Bore/Drill Rigs		
Tractors/Loaders/Backhoes		
	6	

Grading
One Acre

Equipment Type	No. of Equip	hr/day
Rubber Tired Dozers	1	6
Excavators		
Graders	1	6
Scrapers		
Tractors/Loaders/Backhoes	1	7
	3	

Grading
Two Acre

Equipment Type	No. of Equip	hr/day
Rubber Tired Dozers	1	8
Excavators		
Graders	1	8
Scrapers		
Tractors/Loaders/Backhoes	2	7
	4	

Grading
Three Acre

Equipment Type	No. of Equip	hr/day
Rubber Tired Dozers	1	8
Excavators		
Graders	1	8
Scraper		
Tractors/Loaders/Backhoes	2	7
	4	

Grading
Five Acre

Equipment Type	No. of Equip	hr/day
Rubber Tired Dozers	1	8
Excavators	1	8
Graders	1	8
Scrapers		
Tractors/Loaders/Backhoes	3	8
	6	

Construction
One Acre

Equipment Type	No. of Equip	hr/day
Cranes	1	4
Welders		
Excavators		
Forklifts	2	6
Generator Sets		
Tractors/Loaders/Backhoes	2	8
	5	

Construction
Two Acre

Equipment Type	No. of Equip	hr/day
Cranes	1	6
Welders	3	8
Excavators		
Forklifts	1	6
Generator Sets	1	8
Tractors/Loaders/Backhoes	1	6
	7	

Construction
Three Acre

Equipment Type	No. of Equip	hr/day
Cranes	1	8
Welders	3	8
Excavators		
Forklifts	2	7
Generator Sets	1	8
Tractors/Loaders/Backhoes	1	6
	8	

Construction
Five Acre

Equipment Type	No. of Equip	hr/day
Cranes	1	7
Welders	1	8
Excavators		
Forklifts	3	8
Generator Sets	1	8
Tractors/Loaders/Backhoes	3	7
	9	

Coating/Paving
One Acre

Equipment Type	No. of Equip	hr/day
Pavers	1	7
Paving Equipment		
Cement and Mortar Mixers	4	6
Plate Compactors		
Rollers	1	7
Tractors/Loaders/Backhoes	1	7
	7	

Coating/Paving
Two Acre

Equipment Type	No. of Equip	hr/day
Pavers	1	6
Paving Equipment	1	8
Cement and Mortar Mixers	1	6
Plate Compactors		
Rollers	1	7
Tractors/Loaders/Backhoes	1	8
	5	

Coating/Paving
Three Acre

Equipment Type	No. of Equip	hr/day
Pavers	1	8
Paving Equipment	1	8
Cement and Mortar Mixers	1	8
Plate Compactors		
Rollers	2	8
Tractors/Loaders/Backhoes	1	8
	6	

Coating/Paving
Five Acre

Equipment Type	No. of Equip	hr/day
Pavers	1	8
Paving Equipment	2	6
Cement and Mortar Mixers	2	6
Plate Compactors		
Rollers	2	6
Tractors/Loaders/Backhoes	1	8
	8	

Site Preparation
One Acre

Equipment Type	No. of Equip	hr/day
Grader	1	8
Bulldozer		
Excavator		
Scraper		
Tractor/Loader/Backhoe	1	8
	2	

Site Preparation
Two Acre

Equipment Type	No. of Equip	hr/day
Grader	1	8
Bulldozer	1	7
Excavator		
Scraper		
Tractor/Loader/Backhoe	1	8
	3	

Site Preparation
Three Acre

Equipment Type	No. of Equip	hr/day
Grader	1	8
Bulldozer		
Excavator		
Scraper	1	8
Tractor/Loader/Backhoe	1	7
	3	

Site Preparation
Five Acre

Equipment Type	No. of Equip	hr/day
Grader		
Bulldozer	3	8
Excavator		
Scraper		
Tractor/Loader/Backhoe	4	8
	7	

Appendix D1 - Construction Survey By South Coast AQMD

Demolition
Ten Acre

Equipment Type	No. of Equip	hr/day
Rubber Tired Dozers	2	8
Concrete Saw	1	8
Excavators	3	8
Bore/Drill Rigs		
Tractors/Loaders/Backhoes		
	6	

Demolition
Fifteen Acre

Equipment Type	No. of Equip	hr/day
Rubber Tired Dozers	2	8
Concrete Saw	1	8
Excavators	3	8
Bore/Drill Rigs		
Tractors/Loaders/Backhoes		
	6	

Demolition
Twenty Acre

Equipment Type	No. of Equip	hr/day
Rubber Tired Dozers	2	8
Concrete Saw	1	8
Excavators	3	8
Bore/Drill Rigs		
Tractors/Loaders/Backhoes		
	6	

Demolition
Twenty-five Acre

Equipment Type	No. of Equip	hr/day
Rubber Tired Dozers	2	8
Concrete Saw	1	8
Excavators	3	8
Bore/Drill Rigs		
Tractors/Loaders/Backhoes		
	6	

Grading
Ten Acre

Equipment Type	No. of Equip	hr/day
Rubber Tired Dozers	1	8
Excavators	1	8
Graders	1	8
Scrapers		
Tractors/Loaders/Backhoes	3	8
	6	

Grading
Fifteen Acre

Equipment Type	No. of Equip	hr/day
Rubber Tired Dozers	1	8
Excavators	2	8
Graders	1	8
Scrapers	2	8
Tractors/Loaders/Backhoes	2	8
	8	

Grading
Twenty Acre

Equipment Type	No. of Equip	hr/day
Rubber Tired Dozers	1	8
Excavators	2	8
Graders	1	8
Scrapers	2	8
Tractors/Loaders/Backhoes	2	8
	8	

Grading
Twenty-five Acre

Equipment Type	No. of Equip	hr/day
Rubber Tired Dozers	1	8
Excavators	2	8
Graders	1	8
Scrapers	2	8
Tractors/Loaders/Backhoes	2	8
	8	

Construction
Ten Acre

Equipment Type	No. of Equip	hr/day
Cranes	1	7
Welders	1	8
Excavators		
Forklifts	3	8
Generator Sets	1	8
Tractors/Loaders/Backhoes	3	7
	9	

Construction
Fifteen Acre

Equipment Type	No. of Equip	hr/day
Cranes	1	7
Welders	1	8
Excavators		
Forklifts	3	8
Generator Sets	1	8
Tractors/Loaders/Backhoes	3	7
	9	

Construction
Twenty Acre

Equipment Type	No. of Equip	hr/day
Cranes	1	7
Welders	1	8
Excavators		
Forklifts	3	8
Generator Sets	1	8
Tractors/Loaders/Backhoes	3	7
	9	

Construction
Twenty-five Acre

Equipment Type	No. of Equip	hr/day
Cranes	1	7
Welders	1	8
Excavators		
Forklifts	3	8
Generator Sets	1	8
Tractors/Loaders/Backhoes	3	7
	9	

Coating/Paving
Ten Acre

Equipment Type	No. of Equip	hr/day
Pavers	2	8
Paving Equipment	2	8
Cement and Mortar Mixers		
Plate Compactors		
Rollers	2	8
Tractors/Loaders/Backhoes		
	6	

Coating/Paving
Fifteen Acre

Equipment Type	No. of Equip	hr/day
Pavers	2	8
Paving Equipment	2	8
Cement and Mortar Mixers		
Plate Compactors		
Rollers	2	8
Tractors/Loaders/Backhoes		
	6	

Coating/Paving
Twenty Acre

Equipment Type	No. of Equip	hr/day
Pavers	2	8
Paving Equipment	2	8
Cement and Mortar Mixers		
Plate Compactors		
Rollers	2	8
Tractors/Loaders/Backhoes		
	6	

Coating/Paving
Twenty-five Acre

Equipment Type	No. of Equip	hr/day
Pavers	2	8
Paving Equipment	2	8
Cement and Mortar Mixers		
Plate Compactors		
Rollers	2	8
Tractors/Loaders/Backhoes		
	6	

Site Preparation
Ten Acre

Equipment Type	No. of Equip	hr/day
Grader		
Bulldozer	3	8
Excavator		
Scraper		
Tractor/Loader/Backhoe	4	8
	7	

Site Preparation
Fifteen Acre

Equipment Type	No. of Equip	hr/day
Grader		
Bulldozer	3	8
Excavator		
Scraper		
Tractor/Loader/Backhoe	4	8
	7	

Site Preparation
Twenty Acre

Equipment Type	No. of Equip	hr/day
Grader		
Bulldozer	3	8
Excavator		
Scraper		
Tractor/Loader/Backhoe	4	8
	7	

Site Preparation
Twenty-five Acre

Equipment Type	No. of Equip	hr/day
Grader		
Bulldozer	3	8
Excavator		
Scraper		
Tractor/Loader/Backhoe	4	8
	7	

Appendix D1 - Construction Survey By South Coast AQMD

Demolition
Thirty Acre

Equipment Type	No. of Equip	hr/day
Rubber Tired Dozers	2	8
Concrete Saw	1	8
Excavators	3	8
Bore/Drill Rigs		
Tractors/Loaders/Backhoes		
	6	

Demolition
Thirty-four Acre

Equipment Type	No. of Equip	hr/day
Rubber Tired Dozers	2	8
Concrete Saw	1	8
Excavators	3	8
Bore/Drill Rigs		
Tractors/Loaders/Backhoes		
	6	

Grading
Thirty Acre

Equipment Type	No. of Equip	hr/day
Rubber Tired Dozers	1	8
Excavators	2	8
Graders	1	8
Scrapers	2	8
Tractors/Loaders/Backhoes	2	8
	8	

Grading
Thirty-four Acre

Equipment Type	No. of Equip	hr/day
Rubber Tired Dozers	1	8
Excavators	2	8
Graders	1	8
Scrapers	2	8
Tractors/Loaders/Backhoes	2	8
	8	

Construction
Thirty Acre

Equipment Type	No. of Equip	hr/day
Cranes	1	7
Welders	1	8
Excavators		
Forklifts	3	8
Generator Sets	1	8
Tractors/Loaders/Backhoes	3	7
	9	

Construction
Thirty-four Acre

Equipment Type	No. of Equip	hr/day
Cranes	1	7
Welders	1	8
Excavators		
Forklifts	3	8
Generator Sets	1	8
Tractors/Loaders/Backhoes	3	7
	9	

Coating/Paving
Thirty Acre

Equipment Type	No. of Equip	hr/day
Pavers	2	8
Paving Equipment	2	8
Cement and Mortar Mixers		
Plate Compactors		
Rollers	2	8
Tractors/Loaders/Backhoes		
	6	

Coating/Paving
Thirty-four Acre

Equipment Type	No. of Equip	hr/day
Pavers	2	8
Paving Equipment	2	8
Cement and Mortar Mixers		
Plate Compactors		
Rollers	2	8
Tractors/Loaders/Backhoes		
	6	

Site Preparation
Thirty Acre

Equipment Type	No. of Equip	hr/day
Grader		
Bulldozer	3	8
Excavator		
Scraper		
Tractor/Loader/Backhoe	4	8
	7	

Site Preparation
Thirty-four Acre

Equipment Type	No. of Equip	hr/day
Grader		
Bulldozer	3	8
Excavator		
Scraper		
Tractor/Loader/Backhoe	4	8
	7	

Appendix D2 - Building Construction Worker and Vendor Trip Rates

Construction Vendor Trips - Defaults for CalEEMod Based on 2008 SMAQMD Field Survey - South Coast AQMD 2010 Update

				Square Footage			*Raw Data Collection in Field*				
Site	**Location**	**Type**	**# Units**	**Residential Area, sq ft**	**Commerical Area, sq ft**	**Office Area, sq ft**	**Light Duty**	**Medium Duty**	**Heavy Duty**	**Observation Time (minutes)**	**Multiplier to Equate Mins to 8 hrs/day**
Heritage Park	Woodland	Single Family Residential	2,037				13	3	6	37	12.97
Heritage Park (2nd visit)	Woodland	Single Family Residential	2,037				13	3	2	30	16
Yolo Co. Emergency Service	Woodland	Commercial			43,560		2	2	0	30	16
Woodshire	Woodland	Single Family Residential	2,000				5	3	5	35	13.71
Woodshire (2nd visit)	Woodland	Single Family Residential	2,000				10	0	3	30	16
815 H St.	Davis	Multi-Family Residential	8				1	0	0	30	16
Eleanor Roosevelt Cr.	Davis	Multi-Family Residential	60				2	0	0	30	16
Parlin Ranch	West Sac	Single Family Residential	306				2	1	3	30	16
Bridgeway Lakes 2	West Sac	Single Family Residential	487				7	2	0	30	16
The Rivers	West Sac	Single Family Residential	1,139				7	2	0	30	16
The River's Side	West Sac	Single Fam/ Multi Fam/ Comm	29	43,560	3,850		2	2	0	30	16
Carriage Lane	Sacramento	Multi-Family Residential	156				0	2	1	30	16
Promenade	Sacramento	Office/ Comm & Retail			751,000	504,000	10	1	6	40	12
Serenade	Sacramento	Single Family Residential					5	7	2	30	16
1801 L St. Building	Sacramento	Multi-Fam Res/ Comm & Retail	176	48,226	9,600		2	0	0	30	16
800 J Lofts	Sacramento	Multi-Fam Res/ Retail		144,035	50,965		2	1	0	30	16
Marriott Hotel	Sacramento	Multi-Family Res/ Comm	30	80,143	187,000		1	0	1	30	16
Anatolia I	Rancho Cordova	Single Fam Res/ Comm	1,038	7,122,060	631,620		19	15	10	30	16
Pappas Gateway Ctr	Elk Grove	Comm/ Retail			11,200		1	0	2	30	16
Sheldon Place	Elk Grove	Single Family Residential	164				6	2	0	30	16
Laguna Ridge (east pt)	Elk Grove	SF Res/ MF Res/ Office/ Comm & Retail	7,826	1,132,560	2,853,180	307,969	4	5	51	30	16
Laguna Ridge (west pt)	Elk Grove	SF Res/ MF Res/ Office/ Comm & Retail	7,826	1,132,560	2,853,180	307,969	7	8	8	30	16
Total Units/SqFt			27,319	9,703,144	7,395,155	1,119,938					

Appendix D2 - Building Construction Worker and Vendor Trip Rates

Construction Vendor Trips - Defaults for CalEEMod

Based on 2008 SMAQMD Field Survey - South Coast AQMD 2010 Update

	Daily Count			Residential			Commercial			Office			
Site	**Light Duty**	**Medium Duty**	**Heavy Duty**	**Light Duty**	**Medium Duty**	**Heavy Duty**	**Light Duty**	**Medium Duty**	**Heavy Duty**	**Light Duty**	**Medium Duty**	**Heavy Duty**	**References for the Residential SqFt**
Heritage Park	169	39	78	169	39	78	0	0	0	0	0	0	
Heritage Park (2nd visit)	208	48	32	208	48	32	0	0	0	0	0	0	
Yolo Co. Emergency Service	32	32	0	0	0	0	32	32	0	0	0	0	
Woodshire	69	41	69	69	41	69	0	0	0	0	0	0	
Woodshire (2nd visit)	160	0	48	160	0	48	0	0	0	0	0	0	
815 H St.	16	0	0	16	0	0	0	0	0	0	0	0	
Eleanor Roosevelt Cr.	32	0	0	32	0	0	0	0	0	0	0	0	
Parlin Ranch	32	16	48	32	16	48	0	0	0	0	0	0	
Bridgeway Lakes 2	112	32	0	112	32	0	0	0	0	0	0	0	
The Rivers	112	32	0	112	32	0	0	0	0	0	0	0	
The River's Side	32	32	0	29	29	0	3	3	0	0	0	0	http://www.mintierharnish.com/projects/westsac/pdf/2008-2013HousingElementUpdate.pdf
Carriage Lane	0	32	16	0	32	16	0	0	0	0	0	0	
Promenade	120	12	72	0	0	0	72	7	43	48	5	29	
Serenade	80	112	32	80	112	32	0	0	0	0	0	0	Serenade at Regency Park Homeowners Association (916) 925-9000
1801 L St. Building	32	0	0	27	0	0	5	0	0	0	0	0	http://www.kuchman.com/architecture-portfolio/urban/1801L.html
800 J Lofts	32	16	0	24	12	0	8	4	0	0	0	0	http://www.cityofsacramento.org/econdev/development-projects/documents/700-800_K_Street_Final_Proposal_web.pdf
Marriott Hotel	16	0	16	5	0	5	11	0	11	0	0	0	http://sacramento.bizjournals.com/sacramento/business_travel/guide/hotels.html
Anatolia I	304	240	160	279	220	147	25	20	13	0	0	0	http://www.cityofranchocordova.org/Modules/ShowDocument.aspx?documentid=758
Pappas Gateway Ctr	16	0	32	0	0	0	16	0	32	0	0	0	
Sheldon Place	96	32	0	96	32	0	0	0	0	0	0	0	
Laguna Ridge (east pt)	64	80	816	17	21	215	43	53	542	4	6	59	http://sacramento.bizjournals.com/sacramento/stories/2008/05/12/story7.html
Laguna Ridge (west pt)	112	128	128	30	34	34	74	85	85	8	9	9	http://sacramento.bizjournals.com/sacramento/stories/2008/05/12/story7.html
Total Daily Vehicle Trips	1,846	925	1,547										
			Total Daily Vehicle Trips	1,496	701	724	289	204	727	60	20	97	
			Vehicle Trips per Unit or 1k Sq Ft	0.0548	0.0256	0.0265	0.0391	0.0275	0.0983	0.0538	0.0176	0.0863	
			TOTAL Vehicle Trips per Unit or 1k SqFt		**0.1069**			**0.1649**			**0.1577**		

Appendix D2 - Building Construction Worker and Vendor Trip Rates

Construction Vendor Trips - Defaults for CalEEMod Based on 2008 SMAQMD Field Survey - South Coast AQMD 2010 Update

		Commercial and Office Daily Count		
Site	**Commerical and Office Area, sq ft**	**Light Duty**	**Medium Duty**	**Heavy Duty**
Heritage Park	0	0	0	0
Heritage Park (2nd visit)	0	0	0	0
Yolo Co. Emergency Service	43,560	32	32	0
Woodshire	0	0	0	0
Woodshire (2nd visit)	0	0	0	0
815 H St.	0	0	0	0
Eleanor Roosevelt Cr.	0	0	0	0
Parlin Ranch	0	0	0	0
Bridgeway Lakes 2	0	0	0	0
The Rivers	0	0	0	0
The River's Side	3,850	3	3	0
Carriage Lane	0	0	0	0
Promenade	1,255,000	120	12	72
Serenade	0	0	0	0
1801 L St. Building	9,600	5	0	0
800 J Lofts	50,965	8	4	0
Marriott Hotel	187,000	11	0	11
Anatolia I	631,620	25	20	13
Pappas Gateway Ctr	11,200	16	0	32
Sheldon Place	0	0	0	0
Laguna Ridge (east pt)	3,161,149	47	59	601
Laguna Ridge (west pt)	3,161,149	82	94	94
TOTALs	**8,515,093**	**349**	**223**	**823**
		0.0410	0.0262	0.0967
			0.1639	

Consumer Products Summary

Statewide Volatile Organic Compound (VOC) emissions data was obtained from the 2008 California Air Resources Board (CARB) Consumer Product Emission Inventory.[1] Statewide total VOC emissions were 239.6 tons/day.

The statewide total building area is 22,435,267,518 square feet. The general building stock inventory was obtained from the HAZUS-MH software and backup databases prepared by the Federal Emergency Management Agency.[2] This inventory was found to be the most comprehensive statewide data available that included building area for all land use types. The inventory was developed from the following information:

- Census of Population and Housing, 2000: Summary Tape File 1B Extract on CDROM prepared by the Bureau of Census.
- Census of Population and Housing, 2000: Summary Tape File 3 on CD-ROM prepared by the Bureau of Census.
- Dun & Bradstreet, Business Population Report aggregated by Standard Industrial Classification (SIC) and Census Block, May 2002.
- Department of Energy, Housing Characteristics 1993. Office of Energy Markets and End Use, DOE/EIA-0314 (93), June 1995.
- Department of Energy, A Look at Residential Energy Consumption in 1997, DOE/EIA-0632(97), November 1999.
- Department of Energy, A Look at Commercial Buildings in 1995: Characteristics, Energy Consumption, and Energy Expenditures, DOE/EIA-0625(95), October 1998.

Statewide VOCs per building square feet are therefore:
(239.6 tons/day x 2000 lbs/ton) / 22,435,267,518 sq. ft. = ***2.14e-5 lbs/(sq.ft.-day)***

[1] http://www.arb.ca.gov/app/emsinv/emssumcat_query.php?F_YR=2008&F_DIV=-4&F_SEASON=A&SP=2009&F_AREA=CA#5

[2] Detailed information is contained in the HAZUS-MH Earthquake Technical Manual, Chapter 3.2.1.3 available here: http://www.fema.gov/plan/prevent/hazus/

Appendix D3 - Consumer Products Use

Data Grouping	Total VOC (tons/day)	Population*	Total VOC (lbs/person-day)	Total Building Area (Square Feet)	
2003 Survey Commercial *(45.3% of 2003 Land Use Total)*	47.4				
2003 Survey Residential *(48.0% of 2003 Land Use Total)*	50.3				
2003 Survey Industrial *(6.7% of 2003 Land Use Total)*	7.0				
2003 Survey Land Use Total *(42.3% of Grand Total)*	*104.7*			8,600,000,000	from South Coast AQMD draft staff report for consumer products rule
2003 Survey CARB Data Total	186.3	34,650,690	1.08E-02		
2006 Survey CARB Data Total	61.1	36,457,549	3.35E-03		
Grand Total	***247.3***		***1.41E-02***	***22,435,267,518***	from HAZUS-MH, data from late 1990's - early 2000's

*Data from American Communities Survey from the US Census

		Total VOC (lbs/building sq. ft.)	
2008 ARB Emission Inventory (Consumer Products)	***239.6***	*2.14E-05*	Statewide Factor
South Coast AQMD Rule 1143 reduction to 300 g/l	11.3	*2.04E-05*	
(as of 1/1/11) If 25 g/L gets upheld by the courts	17.5	1.98E-05	South Coast AQMD

Degreaser Use on Parking Surfaces

Statewide VOC emissions data from degreasers used for general purposes (aerosols and non-aerosols combined) were obtained from CARB's California Emissions Projection Analysis Model (CEPAM2019v1.03). Using a 2017 base year inventory, CEPAM forecasts emissions for degreasers, among other things, based on growth and control data available at the time of development of the model version. CEPAM estimated 2.00 short tons per day of VOC in 2021, the most recent year with available data.[1]

In San Francisco County, the census indicated that in 2014 there were 166,455 non-residential off-street parking spaces. This was calculated based on the number of publicly accessible car parking spaces minus on-street parking spaces (441,905 – 275,450 = 166,455).[2] Further, CARB's EMFAC2021 (v1.0.0) data shows that there were 268,749 registered cars in San Francisco County in 2014, which results in a 0.6 parking space per registered car (166,455 parking spaces / 268,749 cars).

This analysis applies the San Francisco County parking rate of 0.6 parking spaces per registered car to all of California. Using CalEEMod's default of 400 square feet per parking space, and CARB's EMFAC2021 data of 28,439,815 registered cars in California for the year of 2021, the calculation to estimate the total parking area in California in 2021 is as follows.

28,439,815 cars x 0.6 parking spaces/car x 400 sq ft/parking space = 7,045,904,879 square feet

Thus, the estimate for the statewide parking surface degreaser VOC emission factor in 2021 is calculated as follows.

(2.00 short tons VOC/day x 2000 lbs/short ton) / (7,045,904,879 sq ft) = **5.68×10^{-7} lb VOC/sq ft/day**

[1] Available at: https://ww2.arb.ca.gov/applications/cepam2019v103-standard-emission-tool.
[2] Available at: http://sf.streetsblog.org/2014/05/22/census-sf-has-enough-public-parking-spaces-to-fill-cas-coastline.

Fertilizer/Pesticide Use for City Parks and Golf Courses

Statewide VOC emissions from fertilizers/pesticides for agricultural use for the most recent year with available data, 2020, was obtained from CARB's California Emissions Projection Analysis Model (CEPAM2019v1.03). Using a 2017 base year inventory, CEPAM forecasts emissions for fertilizers/pesticides, among other things, based on growth and control data available at the time of development of the model version. CEPAM estimated 41.62 short tons per day of VOC from fertilizers/pesticides for agricultural (not including structural) in 2021.[3] The inventory data for structural pesticides was excluded from this sum because these chemicals are not utilized for groundskeeping activities associated with maintaining city parks and golf courses.

According to the U.S. Department of Agriculture, the statewide total acres of farm operations in 2020 was 24.3 million acres.[4]

The calculation to determine what the average statewide VOC emissions factor would be from fertilizers/pesticides for agricultural use in the year 2020 is as follows.

(41.62 short tons VOC/day x 2000 lbs/short ton) / (24,300,000 acres * 43,560 sq ft/acre) = **7.86×10^{-8} lb VOC/sq ft/day**

This statewide agricultural VOC emission factor is used as a surrogate emission factor for estimating VOC emissions associated with using fertilizers/pesticides for landscaping city parks and golf courses.

[3] Available at: https://ww2.arb.ca.gov/applications/cepam2019v103-standard-emission-tool.
[4] Available at: https://quickstats.nass.usda.gov/results/7441DB63-2C95-33F5-9320-18EDE52C459E.

Analysis of Building Energy Use Data

The following information describes the steps and assumptions used in preparing building energy intensities used in CalEEMod Version 2022.1 (see Appendix G, Table G-28).

Background

Emissions result from activities in residential and commercial buildings when electricity and natural gas are used as energy sources. CalEEMod calculates criteria pollutant and GHG emissions from building natural gas combustion, and GHG emissions from building electricity use (indirectly emitted at regional fossil fuel–fired power plants).

Within Title 24 of the California Code of Regulations (Building Standards Code) is Part 6, the Building Energy Efficiency Standards (Energy Code). The latest Energy Code is for 2019. The California Energy Commission (CEC) adopted the 2022 Energy Code in August 2021, and it will take effect January 1, 2023 (CEC 2022). The Energy Code contains energy conservation standards applicable to particular end use categories for all new or altered residential and non-residential buildings throughout California.

Methodology

Datasets

The default electricity and natural gas consumption are provided to the user based on 2019 consumption estimates from the CEC's (2020, 2021) 2018–2030 Uncalibrated Commercial Sector Forecast (Commercial Forecast) and the 2019 Residential Appliance Saturation Survey (RASS).

The CEC prepared the Commercial Forecast in October 2019. The Commercial Forecast is generated by a computer model developed by the CEC to forecast electricity and natural gas consumption for commercial building types in California. The data that informs the model includes previous commercial end use surveys, floor space and vacancy estimates (based on econometric and demographic data), adopted building and appliances standards, weather data (cooling and heating degree days), and electricity and natural gas rates. The Commercial Forecast provides energy consumption estimates for 10 commercial end uses: space heating, cooling, ventilation, water heating, cooking, refrigeration, miscellaneous, office equipment, indoor lighting, and outdoor lighting.

The CEC administered the statewide RASS in 2019. The study yielded energy consumption estimates for 27 electric and 10 natural gas residential end uses.

- **Electricity**: conventional heat, heat pump, auxiliary heat, central air conditioning, room air conditioning, evaporative cooler, water heat, solar water heat, range/oven, microwave, dish washer, spa heat, clothes washer, dryer, outdoor lighting, TV, home office, personal computer, pool pump, well pump, furnace fan, attic ceiling fan, miscellaneous, refrigerator, freezer, and total.
- **Natural gas**: primary heat, auxiliary heat, conventional gas water heat, solar water heat with gas backup, range/oven, dryer, pool heat, spa heat, miscellaneous, and total.

CEC's Commercial Forecast and RASS also disaggregate energy consumption end use categories by those that are subject to Title 24 standards and those that are not. CalEEMod provides default building electricity and natural gas use disaggregated into these two categories. The distinction is required to enable accurate calculation of several energy sector emission reduction measures. The following end uses, separated by energy source, are subject to Title 24.

- **Electricity**: space heating, cooling, ventilation, water heating, outdoor lighting, and the majority of indoor lighting.
- **Natural gas**: space heating and water heating.

The following end uses, separated by energy source, are not subject to Title 24.

- **Electricity:** all other end uses, including cooking appliances, clothes washers, electric dryers, refrigeration, office electronics, electric pool/spa heating, well pumping, fans, miscellaneous plug-in uses, and the remainder of indoor lighting.
- **Natural gas:** all other end uses, including range/oven, dryer, pool/spa heating, and other miscellaneous uses.

Baseline Energy Use Calculations

The RASS and Commercial Forecast datasets were used to derive the energy intensities of different end use categories for different land use subtypes in different electricity demand forecast zones (EDFZ). It is important to note that although the RASS was completed in 2019, that does not mean the energy intensity estimates derived from the dataset are representative of buildings constructed in compliance with the energy efficiency requirements of the 2019 Energy Code. For example, of the 40,000 residences surveyed in the RASS, the average residence was constructed in 1974, the oldest residences were constructed in 1935, and the newest residences were constructed in 2015. Therefore, the default energy consumption estimates provided in CalEEMod based on the RASS are very conservative, overestimating expected energy use compared to what would be expected for new buildings subject to the latest Energy Code with more stringent energy efficiency measures. While this is certainly a downside to using the RASS dataset, it is counterbalanced by the fact that this dataset is the only known source that provides energy intensity estimates delineated by EDFZ and land use subtype, both of which are important variables that affect a project's energy consumption (e.g., a retirement community in an EDFZ with a hot climate consumes much more energy per dwelling unit than that same land use in an EDFZ with a temperate climate).

The below sections detail some of the key processing and underlying assumptions made for the RASS and Commercial Forecast.

Commercial Forecast for Non-Residential Buildings

The Commercial Forecast provides electricity and natural gas demand per square foot of building space by EDFZ, land use subtype, and end use for the year 2019.

- There are 28 unique EDFZ shapes in CEC's statewide dataset, all of which are included in CalEEMod (see Figure D-1). The Commercial Forecast only contains data for 19 of the EDFZs. The 9 EDFZs missing from the dataset were assigned a proxy EDFZ listed in the Commercial Forecast based on a manual review of the closest EDFZ that shared the longest border with the missing EDFZ. See Table D-1 for each proxy EDFZ.
- There are 12 building types in the Commercial Forecast. Each of the nonresidential land use subtypes in CalEEMod was matched to the appropriate Commercial Forecast building type. See Table D-2 for each non-residential land use subtype's corresponding building type.
- Based on recommendations from CEC staff, it was assumed that 90 percent of total interior lighting electricity was required by fixtured overhead lighting subject to Title 24 and the remaining 10 percent of lighting electricity was associated with plug-in lamps not subject to

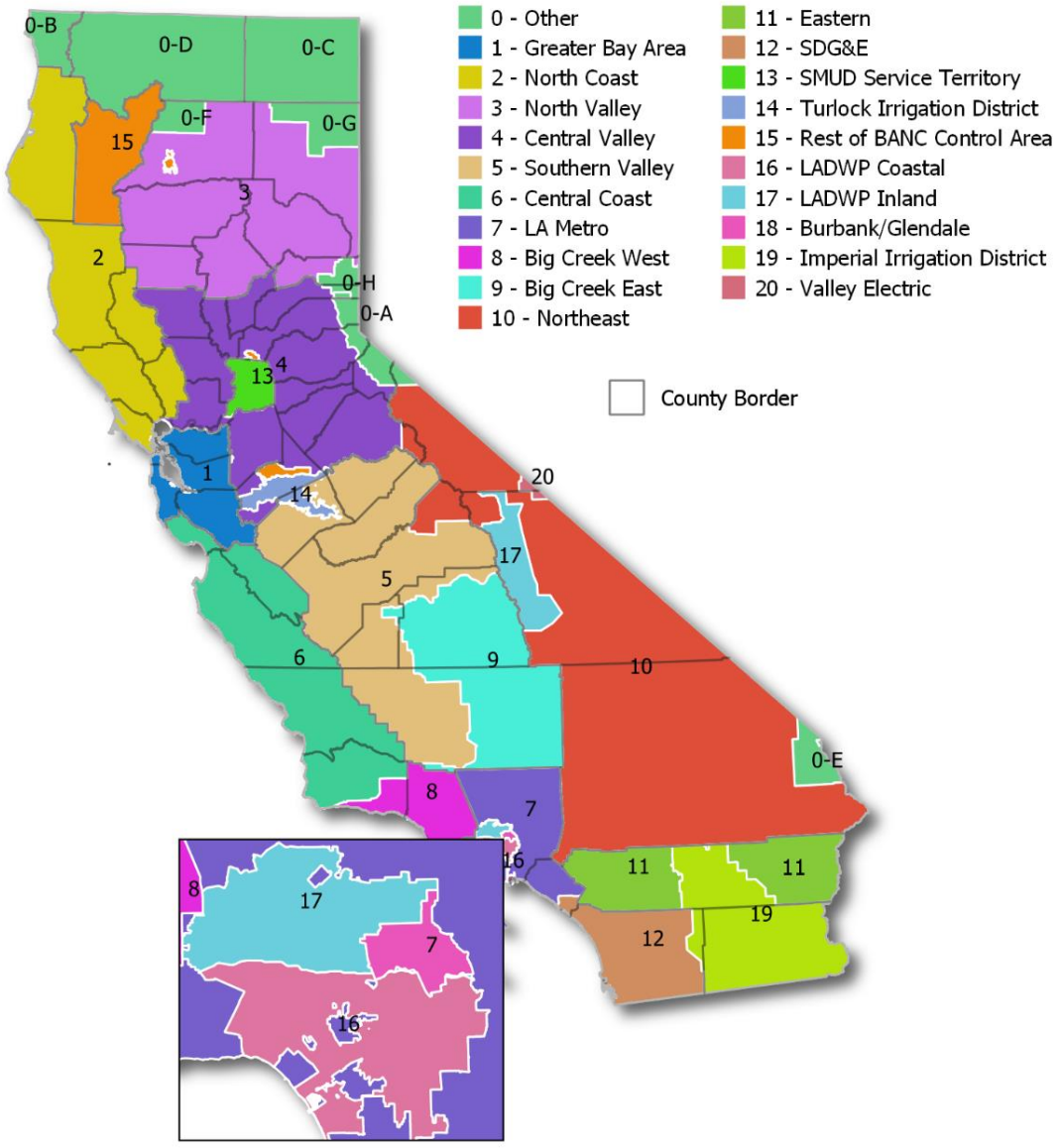
Title 24. The interior lighting electricity was accordingly apportioned 90 percent to Title 24 electricity and 10 percent to non-Title 24 electricity.

2019 RASS for Residential Buildings

The RASS provides unit energy consumption (UEC) of electricity and natural gas and appliance saturations by EDFZ, land use subtype, and end use based on surveys administered in 2019. A UEC represents the amount of energy a single appliance or end use is estimated to use in a single year.

- There are 28 unique EDFZ shapes in CEC's statewide dataset, all of which are included in CalEEMod (see Figure D-1). The RASS only contains data for 15 of the EDFZs. The 13 EDFZs missing from the dataset were assigned a proxy EDFZ listed in the RASS based on a manual review of the closest EDFZ that shared the longest border with the missing EDFZ. See Table D-1 for each proxy EDFZ.
- There are five residential building types in the RASS. Each of the nine residential land use subtypes in CalEEMod was matched to the appropriate RASS residential building type. See Table D-2 for each residential land use subtype's corresponding building type.
- The RASS does not report interior lighting as an end use. Instead, it is a component of the miscellaneous end use category. In an effort to isolate the portion of electricity in the miscellaneous category from interior lighting, it was assumed to represent 20 percent of total electricity, mirroring the assumption of the 2009 RASS (CEC 2010). This value was subtracted from the miscellaneous end use category to avoid double counting.
- The RASS also does not report ceiling fans as an end use. Instead, it is a component of the miscellaneous end use category. In an effort to isolate the portion of electricity in the miscellaneous category from ceiling fans, it was assumed there was an average of one ceiling fan per dwelling use and that it requires 84.1 kilowatt hours per year (NREL 2009). This value was subtracted from the miscellaneous end use category to avoid double counting.
- Based on recommendations from CEC staff, it was assumed that 90 percent of total interior lighting electricity was required by fixtured overhead lighting subject to Title 24 and the remaining 10 percent of lighting electricity was associated with plug-in lamps not subject to Title 24. The interior lighting electricity was accordingly apportioned 90 percent to Title 24 electricity and 10 percent to non-Title 24 electricity.
- Saturation refers to the prevalence of an appliance in the average residence. The saturation data was used to create weighted average residential energy intensity values. For example, perhaps only 30 percent of Apartment or Condo (2-4 Units) dwelling units in EDFZ 4 have electric dryers, which require an average of 500 kilowatt hours per year. Another 30 percent of dwelling units have gas dryers requiring an average of 200 thousand British Thermal Units (kBTU) per year. The remaining 40 percent of dwelling units have no onsite dryer. Therefore, the average Apartment or Condo (2-4 Units) from EDFZ 4 would use 150 kWh per year for electric dryers (30 percent * 500 kWh/yr) and 60 kBTU for gas dryers (30 percent * 200 kBTU/yr).

Figure D-1. California Energy Commission Electricity Demand Forecast Zones



Source: CEC 2017.

Note: This figure is intended to provide a general depiction of the forecast zones as not all details can be clearly depicted at this scale. Those interested in additional detail should refer directly to the interactive version of this map, which is available on CEC's website at the following URL: https://cecgis-caenergy.opendata.arcgis.com/datasets/86fef50f6f344fabbe545e58aec83edd_0/data?geometry=-165.327%2C31.004%2C-72.427%2C43.220.

Table D-1. Electricity Demand Forecast Zones Used in CalEEMod to Proxy Missing Zones

EDFZ Name	EDFZ	Residential (RASS) Proxy Zone	Commercial Proxy Zones
Other-A	0-A	4	4
Other-B	0-B	2	2
Other-C	0-C	3	3
Other-D	0-D	3	3
Other-E	0-E	10	10
Other-F	0-F	3	3
Other-G	0-G	3	3
Other-H	0-H	4	4
Greater Bay Area	1	—	—
North Coast	2	—	—
North Valley	3	—	—
Central Valley	4	—	—
Southern Valley	5	—	—
Central Coast	6	—	—
LA Metro	7	—	—
Big Creek West	8	—	—
Big Creek East	9	—	—
Northeast	10	—	—
Eastern	11	—	—
SDG&E	12	—	—
SMUD Service Territory	13	—	—
Turlock Irrigation District	14	4	—
Rest of BANC Control Area	15	3	—
LADWP Coastal	16	—	—
LADWP Inland	17	—	—
Burbank/Glendale	18	17	—
Imperial Irrigation District	19	11	—
Valley Electric	20	10	10

Source: CEC 2017.
- = N/A. EDFZ is already included in the RASS or commercial end use forecast. Numbers only listed for missing zones.
EDFZ = Electricity Demand Forecast Zone; RASS = Residential Appliance Saturation Study; LA = Los Angeles; LADWP = Los Angeles Department of Water and Power; BANC = Balancing Authority of California; SDG&E = San Diego Gas & Electric; SMUD = Sacramento Municipal Utility District.

Table D-2. Land Use Mapping of Residential Appliance Saturation Study and Commercial Forecast to CalEEMod

Building Type	CalEEMod Land Use Type
College	Junior college (2yr), University/college (4yr)
Grocery	Convenience market (24 hour), Convenience market with gas pumps, Supermarket
Hospital	Hospital
Hotel/motel	Hotel, Motel
Large office	General office building, Government (civic center), Government office building, Industrial park, Medical office building, Office park, Research & development
Miscellaneous	Arena, automobile care center, Bank (with drive-through), Gasoline/service station, General heavy industry, General light industry, Health club, Library, Manufacturing, Movie theater (no matinee), Place of worship, Racquet club
Refg. Warehouse	Refrigerated warehouse
Restaurant	Fast food restaurant w/o drive thru, Fast food restaurant with drive thru, High turnover (sit down restaurant), Quality restaurant
Retail	Discount club, Electronic superstore, Free-standing discount store, Free-standing discount superstore, Hardware/paint store, Home improvement superstore, Pharmacy/drugstore, Regional shopping center, Strip mall
Schools	Day-care center, Elementary school, High school, Junior high school
Small office	n/a
Warehouse	Unrefrigerated warehouse
Single family detached	Single family housing
Apartment or condo (2-4 units)	Apartments low rise, Retirement community
Apartment or condo (5+ units)	Apartments mid rise, Apartments high rise, Condo/townhome high rise, Congregate care
Townhome, duplex, or row house	Condo/townhouse
Mobile home	Mobile home park

RASS = Residential Appliance Saturation Study; Refg. = refrigerated; yr = year; n/a = no mapped land use type.

References

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Introduction

This paper recommends electricity energy use rates to calculate the energy consumption from the operation of car parking facilities in California. The energy uses considered include lighting, ventilation, and elevator use. Recommendations apply to open air parking lots, parking facilities with open walls and access to fresh air, and fully enclosed parking facilities, such as those that are underground, and require ventilation systems. These energy use rates allow the user to calculate lighting, ventilation and elevator use energy impacts separately.

Purpose

This effort was undertaken in conjunction with the CalEEMod Land Use Model ("CalEEMod") 2012 updates. Our intent is to determine if enough information is available to support the development of energy use rates for parking facilities in CalEEMod, and if so, what these recommended energy use rates should be.

Limitations

Energy use rates from water pumps, for fire safety systems or for storm water removal, were not considered because CalEEMod does not include emissions estimates from any stationary sources located at land use development projects. Our research has not identified energy use rates for operational systems, such as from systems designed to collect payments or secure the property, such as computer, ticketing, camera surveillance, or automated and human-activated gate systems. To our knowledge, research is not available to determine in which situations or size of facilities these systems would be utilized. Likewise, research is not available to determine in which situations parking facilities include energy use from natural gas, heating, cooling, and water delivery. Therefore, these energy use rates are not considered.

Proposed Energy Use Rates: Lighting and Ventilation

Energy Star is a joint program of the U.S. Environmental Protection Agency and the U.S. Department of Energy to promote energy efficient products and practices. As part of a larger project to evaluate the efficiency of buildings, Energy Star developed energy factors for parking facilities based on data from the American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE), and a review of existing building codes and local ordinances in the United States. **Table 1** below presents factors for energy use in parking facilities, based on the Energy Star "Performance Ratings Technical Methodology for Parking" technical paper.[i]

Table 1: Energy Use for Lighting and Ventilation by Parking Type			
		Hourly Watts or Horse Power Per Square Foot	**Assumed Hours of Operation**
Open Parking	Lighting	0.15 W/ft^2	16 hours/day
	Ventilation	none	
Unenclosed Parking (no walls)	Lighting	0.30 W/ft^2	24 hours/day
	Ventilation	none	
Fully Enclosed Parking (walls)	Lighting	0.30 W/ft^2	24 hours/day
	Ventilation[(1)(2)]	0.6 hp/1,000 ft^2	

Notes:
1. Ventilation is characterized in terms of flow rate (cubic feet per minute per square foot, cfm/ft^2 equals 0.6 horse power per 1,000ft^2).
2. One horse power(hp) is equal to 0.746 kiloWatts.

Table 2 shows the results of these factors in annual kWh per square foot of parking area.

Table 2: Energy Use for Lighting and Ventilation by Parking Type					
Type of Parking	**Use**	**Days/Year**	**Hours/Day**	**Annual kWh/SqFt**	**Total Annual kWh/SqFt**
Open Parking	Lighting	365	16	0.876	0.876
	(No) Ventilation				
Unenclosed Parking (no walls)	Lighting	365	24	2.63	2.63
	(No) Ventilation				
Fully Enclosed Parking (walls)	Lighting	365	24	2.63	6.55
	Ventilation			3.92	

The Energy Star energy rates are generally consistent with California Title 24 standards. The Title 24 year 2008 standard for indoor parking structure lighting is 0.30 Watts per foot squared; Title 24 year 2005 outdoor parking lighting standard is 0.15 Watts per foot squared; and the proposed Title 24 year 2013 standard for ventilation is 0.6 horse power per 1,000 feet squared[ii]. We have not identified any other sources to compare these factors to that are more appropriate. Note that the energy intensity of parking structures is one of the few land uses that the California Energy Commission (CEC) does not include in the California Commercial End-Use Survey (CEUS) analysis[iii].

None of the other land uses already accounted for in CalEEMod have energy use rates as low as the Energy Star rates for parking facilities, and this is to be expected. Based on the analysis above, parking facilities use between 0.05 and 0.40 kW per square foot per year, and this is much lower when compared to some of the land uses already represented in CalEEMod. The lower end of electric energy rates in CalEEMod includes manufacturing, unrefrigerated warehouses and racquet ball clubs. Depending upon the climate zone, CalEEMod estimates the kW per square foot in unrefrigerated warehouses to be between 3 and 10 kW, and for racquet clubs between 2 and 12 kW. While this doesn't confirm the appropriateness of the Energy Star energy use rates, it is reasonable that parking facilities would have lower energy use rates than other uses.

Proposed Energy Use Rates: Elevators

There are various elevator energy calculations available on the web[iv]. To our knowledge, none are independently verified by a public, private or government agency. This section presents three energy use rates for elevators. Energy use rates will depend on the manufacturer, the type and size of elevator, how many floors the elevator serves, the idle mode settings selected, how often the elevator is used and with how many people. For example, buildings with seven or fewer floors may use elevators powered by hydraulic motors, whereas buildings with eight or more floors will need more powerful and energy-intense "geared or gearless traction" elevators. These elevators are driven by direct current motor-generator sets (DC MG), silicon controlled rectified (SCR) DC motors, or variable voltage variable frequency (VVVF) drives coupled to alternate current (AC) motors. All of these configurations provide variable and high-speed operation and provide regeneration, but exhibit different operating efficiencies[v].

For our purposes, it is assumed that a parking structure elevator will serve ten or fewer floors. Elevators serving more than 10 floors are likely to be located in buildings with uses in addition to parking, and therefore CalEEMod will assume the energy use rates (including elevator use) associated with the other land uses in its calculations.

Table 3 presents the **first example**. Dover Elevators has calculated the average kWh required per day for a single elevator equipped with MG, SCR, and VVVF drives. Based on these daily estimates, Table 3 calculates the per hour and annual energy use for two to five floors and six to ten floors based on the type of elevator technology employed.

Table 3: Average Energy Consumption (kWh) for 2,500 Pound Capacity Elevators (1)						
Number of Floors	**kW Energy Use Based On How Electrical Current is Controlled (per hour)**					
	Variable Voltage Variable Frequency (VVVF)		Silicon Controlled Rectified *(SCR)*		DC MG Sets *(MG)*	
2 to 5	3.875		6.625		9	
6 to 10	4.875		6.75		9.5	
Number of Floors	**kW Energy Use Based On How Electrical Current is Controlled (per year)** (2)					
	16 hrs/day	24 hrs/day	16 hrs/day	24 hrs/day	16 hrs/day	24 hrs/day
2 to 5	22,630	33,945	38,690	58,035	52,560	78,840
6 to 10	28,470	42,705	39,420	59,130	55,480	83,220

Notes:
1. Based on calculations from Dover Elevators.
2. Combines calculations from Dover Elevators and Energy Star assumptions about hours of operations per day.

The **second example** is cited in the California Energy Commission (CEC) *2013 Nonresidential ACM Manual – Draft Version*, June 2011, (the "CEC Draft Manual")[vi]. These estimates are based on a TIAX

report cited by the U.S. Energy Information Administration entitled, "Commercial and Residential Spector Miscellaneous Electricity Consumption: Y2005 and Projections to 2030" (the "TIAX Report") and includes buildings with at least 50 percent of space dedicated to non-residential uses, including agricultural, industrial, schools, and institutional uses[vii]. **Table 4** below presents unit energy consumption data from a sample of approximately 5,200 buildings for 2,500 pound capacity elevators, based on time spent in different elevator modes – active, ready, standby, and off:

Table 4: Average Energy Consumption (kWh) for 2500 Pound Capacity Elevators (1)				
Elevator Mode	**Percent of Time in Each Mode**	**Annual Hours in Each Mode**	**kWh Use in Each Mode**	**Annual kWh**
Active	3%	300	10	300
Ready	84%	7,365	0.5	3683
Standby	13%	1,095	0.25	274
Off	0%	0	0	0
Total	100%	8760 (2)	11	6,956 (3)

Notes:
1. TIAX LLC. *Commercial and Residential Spector Miscellaneous Electricity Consumption: Y2005 and Projections to 2030*. September 22, 2006.
2. Assumes operation 365 days per year for 24 hours per day.
3. This energy use represents rates from 2003 projected out to 2005. Year 2005 shows only a slight decrease from the year 2003 baseline.

The differences in energy use estimates in Table 3 and Table 4 is astonishing. The TIAX Report estimates the energy use from the average 2,500 pound capacity elevator to be approximately 20 percent of the kWhs needed for a 24-hour day of the least-energy intensive elevator in the Dover estimates.

The **third example** is based on calculations provided by Kone Elevators documenting the energy savings between a hydraulic elevator and Kone's elevators with the most energy efficient features selected.[viii] These features include energy-saving LED lighting, standby modes for lights, signalization, ceiling fans, and destination control systems, a lightweight hoisting system, and energy regenerating technology. According to Kone, the bulk of energy use in hydraulic elevators comes from the hoisting system. **Table 5** below is based on the information presented by Kone on annual energy consumption from hydraulic elevators and its "EcoSpace" option.

Table 5: Kone Average Energy Consumption (kWh) for 3500 Pound Capacity Elevator (1)			
Energy Use	**Hydraulic Elevator (kWh/year)**	**Kone EcoSpace Elevator (kWh/year)**	**Percent Reduction**
Lighting	2,015	153	- 92%
Electrification	1,139	1,360	+19%
Hoisting	6,024	895	-85%
Total	9,178	2,408	-74%

Notes:
1. Based on information provided by Kone, Inc.

These estimates are based on a 3,500 pound capacity serving four floors with 200,000 starts per year, or 34 starts an hour, assuming 16 hours of operation per day.

Evaluation of Data

It is a challenge to compare the three available examples. The Dover (*first example*) data are detailed and offer specifics about energy use based on the types of elevator systems, but no information on the usage, such as hours per day of operation, speed, or starts per day. This source also presents energy consumption much higher than the other two sources. The Dover information was collected from a website maintained by Washington State University and the Western Area Power Administration and is not dated. It is not clear if these data are current. The Kone (*third example*) estimates are also based on very specific elevator specifications that will not necessarily transfer to our application, which requires a much more general approach. It is not anticipated that CalEEMod users will have detailed information about the size, capacity, usage rates, and type of elevators (hydraulic, geared or gearless traction, etc.) or other specifications, such as type of lighting or ceiling fans selected.

The CEC Draft Manual reports that that elevators are custom designed for each building and "little information is known on how to model elevators." Our research also resulted in few sources that were either specific to the manufacturer or very general.

TIAX (*second example*) is a reliable and reputable company who has conducted a robust study (5,200 buildings) of a variety of elevator types that would be more reflective of the real world and provides a simpler and direct method of determining energy use from an average-used elevator. The question still remains as to whether there is a standard in determining the number of elevators for a size of a parking lot. However, aside from the Americans with Disabilities Act requiring "one passenger elevator serving each level in all multi-story buildings," a building code does not seem to exist requiring how many per size or square footage. It should be noted that the Americans with Disabilities Act does allow parking structures that provide the correct number of accessible spaces on the ground floor to not install an elevator[ix]. As elevators would increase building costs and consume valuable square feet, it seems reasonable to conclude that parking structures are constructed with as few elevators as required by local building codes.

The TIAX Report does include energy use rate projections for a selected future year (2015, 2020, etc.) based on project build out year[x] but, at this time, such programming would be more complex and would require more information from the User. Thus, it is concluded for the default to use a fixed value in time.

Ultimately, decisions regarding the number of elevators is left to the developer who may choose based on a number of reasons. However, there are other sources, including this "rule of thumb" based on all modern American construction (not just commercial buildings):

Table 6: Estimates for Number of Elevators Needed [1]			
No. of Floors	**Building Meters Squared (gross)**	**Building Square Feet (gross)**	**Recommended No. of Elevators**
Up to 3	5,000	53,820	1
4 or more	6,000	64,583	2
4 of more	10,000	107,639	3

Notes:

1. Bhatia, A. *Building Elevator Systems*, CED Engineering.com. Course No: A06-001. Note that if elevators are distributed throughout the building, instead of at a centralized bank of elevators, to account for inefficiencies and imbalances in demand, increase the number of elevators by 60 percent.

Using TIAX study conclusion that one 2500 pound elevator consumes 7,000 kWh per year (**Table 4**) and the number of elevators for a particular sized parking lot (**Table 6**), data can be extrapolated to determine the energy factor to apply (**Table 7**).

Table 7: Annual kWh per Square Foot			
Gross Sq Ft	Elevators	Annual kWh	Annual kWh/square foot
54,000	1	7000	0.13
65,000	2	14000	0.22
108,000	3	21000	0.19
162,000	4	28000	0.17
216,000	5	35000	0.16
270,000	6	42000	0.16
324,000	7	49000	0.15
378,000	8	56000	0.15
432,000	9	63000	0.15
486,000	10	70000	0.14
540,000	11	77000	0.14
594,000	12	84000	0.14
648,000	13	91000	0.14
702,000	14	98000	0.14
756,000	15	105000	0.14
810,000	16	112000	0.14
864,000	17	119000	0.14
918,000	18	126000	0.14
972,000	19	133000	0.14
1,026,000	20	140000	0.14
1,080,000	21	147000	0.14
1,134,000	22	154000	0.14
1,188,000	23	161000	0.14

Conclusion

For the purposes of estimating energy use rates in parking lots and structures in California, CalEEMod should base energy use rate assumptions on the Energy Star estimates for lighting and ventilation. That would require CalEEMod to establish the following new sub-land uses (*with energy impact calculated*) under Parking:

1. Parking lot (*lighting energy use only*)
2. Unenclosed parking structure (*lighting energy use only*)
3. Enclosed parking structure (*lighting and ventilation energy use*)
4. Unenclosed parking structure with elevator (*lighting and elevator energy use*)
5. Enclosed parking structure with elevator (*lighting, ventilation, and elevator energy use*)

The default energy factor (annual kWh/square foot) recommended and used in CalEEMod is 0.19 annual kWh/sq ft which is based on the real data in Tables 4 and 6 and not the highest or lowest factor. CalEEMod will provide the ability for the User to override the default factor if the number of elevators is known (per total square feet) and is different than the default. For example, if a parking lot structure is known to be 200,000 sq ft with 6 elevators, then using the 7,000 annual kWh/elevator x 6 elevators is 42,000 annual kWh/200,000 sq ft equals a new factor of 0.21 annual kWh/sq ft that would be used to replace the CalEEMod default factor of 0.19 annual kWh/sq ft. In addition, if new data is known about kWh usage from a particular elevator (e.g., green elevator technology), the same methodology could be applied replacing the 7,000 annual kWh/elevator with a new known value.

Endnotes

[i] www.energystar.gov/ *Energy Star Performance Ratings Technical Methodology for Parking*. http://www.energystar.gov/ia/business/evaluate_performance/parking_tech_desc.pdf.

[ii] Parking and Title 24 standards: We have not adjusted the outdoor parking lighting factors in the Energy Star to meet 2008 or proposed 2013 Title 24 standards, which are lower than 2005 requirements, because additional lighting is often allowed in outdoor zones that are considered in need of additional safety lighting.

[iii] California Energy Commission. http://www.energy.ca.gov/ceus/

[iv] For example, see http://www.thyssenkruppelevator.com/energy%20calculator/energy.aspx and http://www.kone.com/media/en_US/green/index.html

[v] Washington State University and Western Area Power Administration. Energyexperts.org. http://energyexperts.org/EnergySolutionsDatabase/ResourceDetail.aspx?id=1709

[vi] CEC 2013 Nonresidential ACM Manual – Draft Version (CEC Alternative Calculation Method – June 2011). http://www.energy.ca.gov/title24/2013standards/prerulemaking/documents/2011-06-21_workshop/review/2013_NACM_Approval_Manual_Draft.pdf. The CEC website reports the final document will be released in January 2013.

[vii] TIAX LLC. *Commercial and Residential Spector Miscellaneous Electricity Consumption: Y2005 and Projections to 2030*. September 22, 2006. http://wpui.wisc.edu/news/EIA%20Posts/TIAX_EIA_MiscElecReport.pdf

[viii] Kone. *Kone Eco-efficient Solutions* (Brochure); *Elevator Energy Calculation Report*, 10/11/2011. Provided by Kone, Inc.

[ix] Email communication with the US Access Board (tel: 800-872-2253 email: ta@access-board.gov). The US Access Board referred us to local building codes to determine elevator requirements.

[x] Table 4 above presents the 2003 energy use average projected to 2005. The TIAX Report projects elevator energy use rates out in 5 year increments to 2030, however, the estimated decrease in energy use is slight between year 2005 and 2030 and unlikely to affect model results.

Three Studies were Conducted in 2012 on the Amount of Parking Lot Area was Painted (for parking stalls, markings, etc)

Since the release of CalEEMod v2011.1.1, the percentage of space in parking lots that is painted has been questioned, so it was decided to re-evaluate the default currently used. A literature search was performed, but no studies were identified that provided information on the amount of coatings used for parking lots. As a result, contractors were contacted to assist in this research effort. It was determined that most contractors contacted use large volume containers of coatings and do not keep record of the specific amount used on individual parking lot jobs. Consequently, three of the California air district provided data on their own lots and the size of area painted to generate the following data. The compilation relies on the assumption that only one coat of paint was used to make the markings (e.g., stall lines, handicap symbols, no-parking curbs, traffic direction arrows, etc.). The results of the three studies showed a range in percentage of coatings applied. Because the sample size is so small, it was decided to set the default at the highest percentage of the 3 studies (6 percent of total square footage area). Using the highest percentage would also generate a more conservative impact evaluation of VOC emissions from coatings on parking lots. As additional information is obtained the default will be reevaluated and modified as necessary.

SMAQMD Parking Garage Painted Area Calculation (May 15, 2012)

19,000	Gross square footage of parking garage
1,000	Subtract office, storage cage, etc.
18,000	Net parking garage square footage
17	2 deep parking stalls
3456	square inches for a 2 deep parking stall paint
407.7	**square feet for 17 2 deep parking stalls paint**
12	3 deep parking stalls
5376	square inches for a 3 deep parking stall paint
447.7	**square feet for 12 3 deep parking stalls paint**
4	disabled parking stalls
2160	square inches for 1 handicapped parking stall paint
60.0	**square feet for 4 handicapped parking stalls paint**
36.0	**square feet of paint for handicapped square parking signs (4 of them)** (3 feet x 3 feet squares)
14.0	**square feet of no parking signs next to handicapped stalls (4 of them)** (3.5 feet x 1 feet rectangles)
77.0	**square feet of extra space/diagonals handicapped area next to and above parking stall** (5 8 feet diagonals, 4 11 feet diagonals, 5 6 feet diagonals, 13 9 feet diagonals)
1042.4	**square feet for paint in SMAQMD parking garage**
5.8%	**percent of total square footage of parking garage**

4	inches - width of stall painted line
192	inches - length of side stall line
96	inches - length of top stall line
4	inches - width of stall painted line
216	inches - length of side stall line handicapped
108	inches - length of top stall line handicapped

Actual Surface Area Painted & Emissions - South Coast AQMD Parking Lot (June 2012)

Line Type	Width (ft)	Length (ft)	Quantity	Total Painted Surface Area (sq ft)
Parking Stall Lines	0.33	18	224	1343.87
"Compact" Denotation	1.00	5	7	35.00
Arrows	4.00	3.5	6	84.00
"Slow 5 MPH" Denotation	5.00	6	2	60.00
Handicap Lines	0.33	18	8	48.00
Handicap Symbol	3.00	3	4	36.00
No Parking Red Curbs	0.50	32	4	64.00
No Parking Red Curbs	0.50	13	2	13.00
No Parking Red Curbs	1.00	20	1	20.00
No Parking Red Curbs	0.50	11	2	11.00
"Stop" Denotation	6.00	8	1	48.00
			A_{actual} =	1763 Total Actual Painted Surface Area (sq ft) South Coast
				37,869 AQMD Repaved Parking Lot Area (sq ft)
				4.7% **% Painted Using Single Coat**

NOTE: The South Coast AQMD's parking stalls were separated by single lines (112), however, most commercial/recreational parking lots use double lines (224).

Actual Surface Area Painted & Emissions - SLO County APCD Parking Lot (June 2012)

Line Type	Width (ft)	Length (ft)	Quantity	Total Painted Surface Area (sq ft)	Width (inches)
Parking Place	0.33	18	29	174.00	4
Handicap Lines	0.33	9	5	15.00	4
Handicap Symbol	3.50	3.5	1	12.25	-
Bike Locker Protection	0.33	4	7	9.33	4
Red Curbs - Horizontal Paint	0.33	232	1	77.33	4
Red Curbs - Vertical Paint	0.50	232	1	116.00	6
			A_{actual} =	404	Total Actual Painted Surface Area (sq ft)
				14,900	APCD Parking Lot Size (sq ft)
				2.7%	**% Painted Using Single Coat**

Default Water Use Determination for Industrial Land Uses *(for Version 2013.2 and later)*

Since the release of CalEEMod v2011.1.1, the default water usage from industrial land uses has been questioned, so it was decided to re-evaluate the default currently used. The following are the assumptions used to determine the operation period of a typical industrial facility and the published water usage values (see web link). Specifically for industrial land use categories, the default water use rate is 925 gallons/workday/thousand square feet. This value was computed by dividing the annual water use in California industry (Table ES-6 in Gleick et al. 2002) by the industrial work area in California (Dun & Bradstreet, Business Population Report aggregated by Standard Industrial Classification (SIC) and Census Block, May 2002) where 225 was the annual number of workdays in a year.

365	days/year
7	days/week
52.14	weeks/year
5	Workdays/week
260.71	Potential Workdays/year
36	Average Holidays + Maintenance Shutdowns/year
225	Probable Days/year of Industrial Operations
AF	Acre-foot
SF	Square-foot

225	Industrial Work Days - *see CalEEMod User Manual Appendix A*
665	TAF; *Best Estimate of Water Use/year by California Industry - As identifed in Table ES-6 of Gleick et al. 2003* : www.pacinst.org/reports/urban_usage/waste_not_want_not_full_report.pdf
2,955.6	AF/Work Day ; *Best Estimate of Water Used by CA Industry/Industrial Work Day*
325,851.4	Gal/AF (*conversion)*
963,071,916	Gal Used by CA Industry/Industrial Work Day
1,041,386	TSF of Industrial Work Area in CA - *As identified by: Dun & Bradstreet, Business Population Report aggregated by Standard Industrial Classification (SIC) and Census Block, May 2002, the Industrial component reference identfied in the CalEEMod User Manual Appendix D3 on Consumer Products.*
925	**Gals/WorkDay/TSF**

Default Solid Waste Generation for Industrial Land Uses *(for version 2013.2 and later)*

Since the release of CalEEMod v2011.1.1, the default solid waste generation from industrial land uses has been questioned, so it was decided to re-evaluate the default currently used. There is limited information available linking employment and solid waste generation for the various individual industrial land uses types as analyzed in CalEEMod. However, the Southern California Association of Governments (SCAG) that represents the six-county region of Los Angeles, Orange, Ventura, Riverside, San Bernardino and Imperial counties conducted a study in 2001 called the 'Employment Density Study' (http://www.scag.ca.gov/forecast/downloads/employ_den.pdf). Given the known challenge in locating statewide data and the fact that SCAG data represents close to half the state's population, the information is quasi-applicable to the state. In the study, SCAG identifies the following region-wide median employment densities for these specific industrial land use types:

Light manufacturing = 924 square foot (sq ft)/employee
Warehouse = 1,225 sq ft/employee

Using the 1999 CalRecycle Waste Characterization generation rate of 1.15 tons/employee/year, it has been determined to modify the current default of solid waste generation for industrial land use types using the following rates in CalEEMod:

Warehouses (all types) = 0.94 tons/1000 sq ft/year
All other industrial = 1.24 tons/1000 sq ft/year

Employee based rate for all industrial uses = 1.15 tons/employee/year

These rates seem more in line with other land use generation rates and also have the advantage of using employment densities that correspond more closely with trip generation rates.

Default N Load Factor for Wastewater Calculations *(for version 2013.2 and later)*

Since the release of CalEEMod v2011.1.1, the Sanitation Districts of Sacramento and Los Angeles have raised a concern that the default N load factor of 40mg/L from USEPA's database (2008) is too high. The N load is the mass of nitrogen dischared per volume of wastewater effluent. The factor is used in calculating nitrous oxide emissions produced when treated wastewater is discharged in aquatic environments such as rivers and estuaries. A high N load factor will overestimate the GHG emission throughout much of the State. US EPA has provided an online database (http://cfpub.epa.gov/dmr/ez_search.cfm) for plant-specific effluent results for various pollutants including nitrogen. Performing a query just for California, calculations show that the statewide average would be **26 mg/l** instead of 40 mg/l (current default). CalEEMod does not, at this time, allow the user to enter plant-specific numbers, so the default offers a more representative number for the state.

The following equation was used to determine statewide average:

$$Flow{-}weighted\ effluent\ Nitrogen\ in\ California\ (mg/L){=}203{,}953{,}373\ (N{-}lbs)/year *(2586502000\ Gals/day)\text{^}(-1)*(1year/(365.25\ days))*(453592.37mg/1lb)*(1Gal/3.785l){=}\mathbf{25.87\ mg/l}$$

The following data was retrieved from the USEPA database (2013) for the equation:

Source: http://cfpub.epa.gov/dmr/ez_search.cfm

Statewide Sum:	203,953,373 lb/yr	2,586,502,000 gal/day	

Calif POTWs	Total Pounds (lbs/yr)	Average Flow (MGD)	
CA0107417*	1,020,535	17.4	*Corrected to reflect actual
CA0107611*	755,263	15.4	plant effluent as per discussion
CA0053813	47,848,683	273	with plant facility staff
CA0109991	46,073,447	267	
CA0107409	15,195,624	267	
CA0110604	12,660,447	152	
CA0077682	12,360,199	146	
CA0037664	9,556,191	148	
CA0037702	7,402,404	66.25	
CA0037869	5,197,299	61.4	
CA0038008	5,197,299	61.4	
CA0037613	4,822,150	57.3	
CA0037648	3,237,605	39.5	
CA0107395	2,620,463	24.6	
CA0054097	2,102,347	21.6	
CA0037681	1,886,655	32.4	
CA0053911	1,450,084	57.01	
CA0038318	1,284,429	1.18	
CA0107433	1,113,164	12.4	
CA0037737	962,571	6.88	
CA0048551	949,029	8.038	

CA0037541	913,876	12.2
CA0048194	904,330	8.46
CA0038130	860,572	9.29
CA0038547	778,946	8.77
CA0038628	762,472	9.31
CA0056227	727,201	27.7
CA8000304	709,805	34.8
CA0105350	683,282	29.4
CA8000409	608,790	26.7
CA0038024	562,781	4.606
CA0054011	553,291	19.6
CA0104523	525,445	3.69
CA0079189	504,795	8.46
CA0038539	484,861	8.94
CA0048216	479,712	5.09
CA0048160	456,062	4.054
CA0053856	417,294	13.09
CA0048143	367,016	15.2
CA0054119	362,093	12.2
CA0053953	352,926	14.2
CA0049224	349,790	3.89
CA0107981	349,112	10.3
CA0079103	344,510	10.6
CA0079260	333,956	3.069
CA0104973	316,751	4.015
CA0056294	285,797	9.77
CA7000009	283,784	2.73
CA0037788	262,829	3.41
CA0079219	261,626	8.013
CA0037796	255,924	3.082
CA0108031	254,610	1.21
CA0037842	244,169	100
CA0055221	241,546	8.83
CA0054216	202,111	14.5
CA0104426	196,783	3.54
CA0053651	194,981	5.63
CA0053716	190,189	8.047
CA0038091	182,140	2.52
CA0079138	168,719	26.6
CA0105295	165,877	5.89
CA8000188	162,763	6.23
CA0037532	160,569	1.53
CA0055531	154,954	6.71
CA0104400	145,679	1.24
CA0053619	142,296	4.83
CA0022764	115,563	4.27
CA0054313	110,962	4.97

CA0084573	100,294	6.54
CA0053597	97,150	3.18
CA0082589	94,621	3.37
CA0047996	92,294	0.71
CA8000316	86,643	5.74
CA0079235	84,324	2.97
CA0082660	80,744	3.23
CA0105015	76,603	0.72
CA8000027	74,164	8.066
CA0079651	73,795	1.15
CA0037575	71,906	8.35
CA0056014	67,209	3.36
CA0079154	63,785	9.06
CA8000383	59,920	2.81
CA0079731	59,579	7.42
CA0037621	58,350	11.05
CA0079197	57,484	3.92
CA0079049	52,185	4.65
CA8000326	47,842	3.42
CA0038067	40,548	1.54
CA0079111	36,353	49.2
CA0102695	35,497	0.96
CA0022888	35,088	1.93
CA0077704	34,804	1.22
CA0085235	34,282	1.96
CA0038598	30,598	1.68
CA0037753	30,300	0.63
CA0078671	29,039	1.601
CA0102822	28,556	8.65
CA0037826	27,040	0.74
CA0037711	26,202	2.76
CA0053961	25,767	1.99
CA0109045	24,679	3.54
CA0079022	23,671	0.89
CA0105619	19,761	3.77
CA0023345	19,753	0.91
CA0079511	18,563	0.97
CA0037834	18,079	20.1
CA0079243	16,843	3.025
CA0048127	15,525	2.83
CA0037810	13,909	4.104
CA0022756	13,284	1.67
CA0037851	12,955	2.25
CA0081434	12,534	1.209
CA0079316	12,134	2.201
CA0023060	12,025	0.74
CA0081558	11,221	5.702

CA0078981	10,228	0.54
CA0085260	9,257	0.34
CA0105376	8,569	2.82
CA0037800	7,266	2.18
CA8000395	6,652	0.58
CA0024449	6,336	9.048
CA0054372	6,277	0.38
CA8000100	5,890	0.81
CA0078891	4,768	1.48
CA0038776	4,591	3.017
CA0084727	4,292	0.107
CA0077712	4,075	1.56
CA0107492	3,943	0.84
CA0022730	3,912	0.42
CA0038768	2,485	3.019
CA0084239	2,480	0.063
CA0078948	2,146	9.86
CA0025135	1,521	1.12
CA0078662	1,493	4.71
CA0037770	1,309	1.72
CA0084271	1,252	0.54
CA0048151	1,059	1.074
CA0079898	787	2.25
CA0079081	749	6.54
CA0047364	743	1.33
CA0079502	706	9.209
CA0078956	613	0.74
CA0078590	481	1.65
CA0083771	480	0.19
CA0004995	418	0.71
CA0047899	248	0.95
CA0084476	216	2.15
CA0078034	194	0.73
CA0107999	191	1.77
CA0077828	184	0.38
CA0085201	117	0.095
CA0077836	115	1.57
CA0024490	0.033	4.40E-07
CA0005241	0	0
CA0022977	0	0
CA0023355	0	0
CA0048828	0	0.71
CA0049675	0	0
CA0059501	0	0
CA0064556	0	0
CA0077691	0	8.45
CA0077950	0	5.078

CA0081485	0	0
CA0108944	0	0
CA0110116	0	0.34
	203,953,373	**2586.50**

Additional Construction Defaults

Construction surveys and literature review to inform the additional construction defaults are currently ongoing. This appendix will be updated and republished with recommended defaults once the analysis is complete.