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Supplement of

Estimating criteria pollutant emissions using the California Regional Multi-sector Air Quality Emissions (CA-REMARQUE) model v1.0

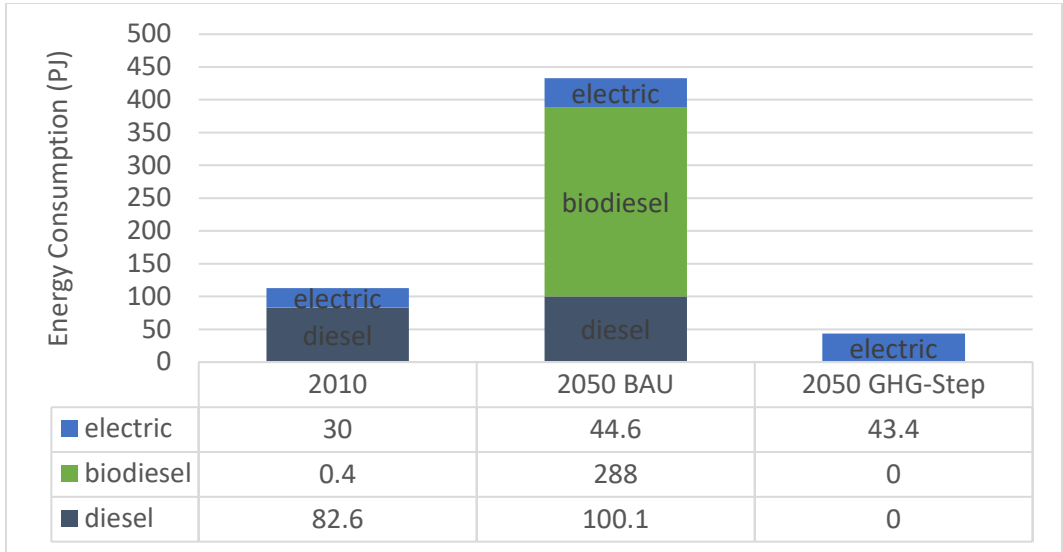
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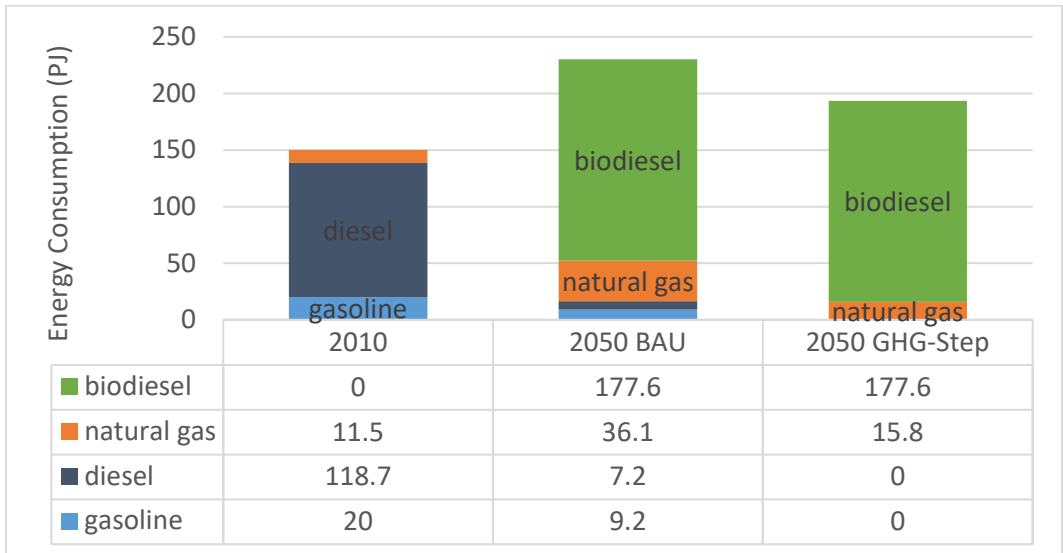
Supplementary Information



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Figure S1: CA-TIMES' energy consumption by fuel type and scenario for rail.

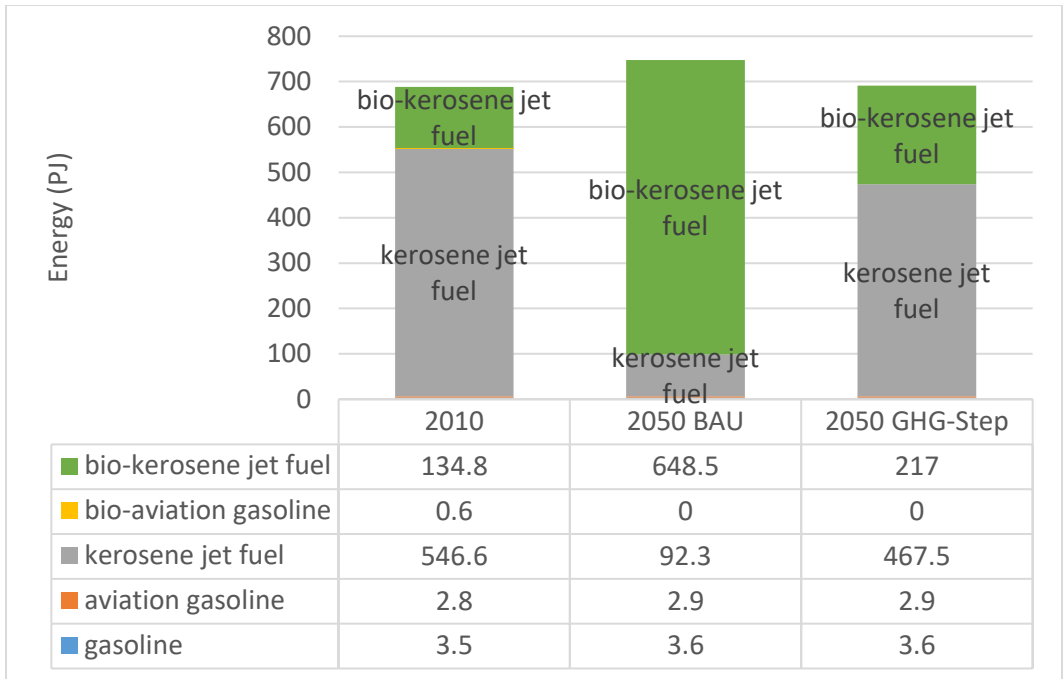
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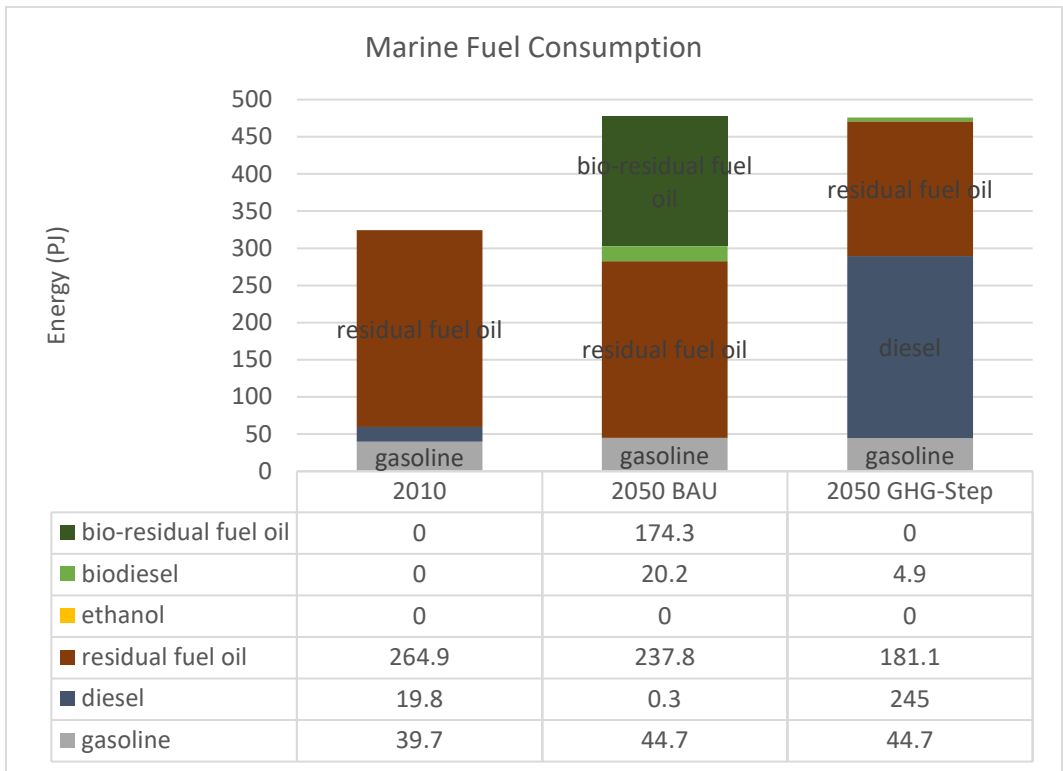
Figure S2: CA-TIMES Energy consumption by fuel type and scenario for off-road vehicles.

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15 **Figure S3: CA-TIMES' energy consumption by fuel type and scenario for aircraft.**

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18 **Figure S4: CA-TIMES' fuel consumption by fuel type and scenario for marine.**

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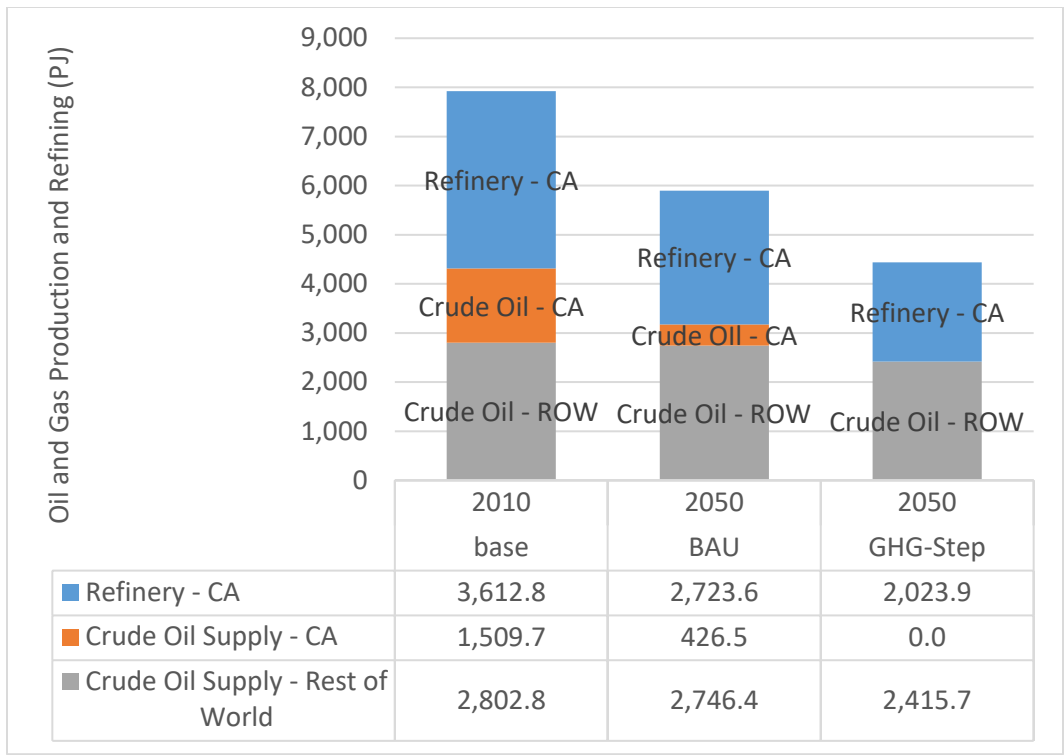
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Figure S5: SWITCH electricity service load areas within California.

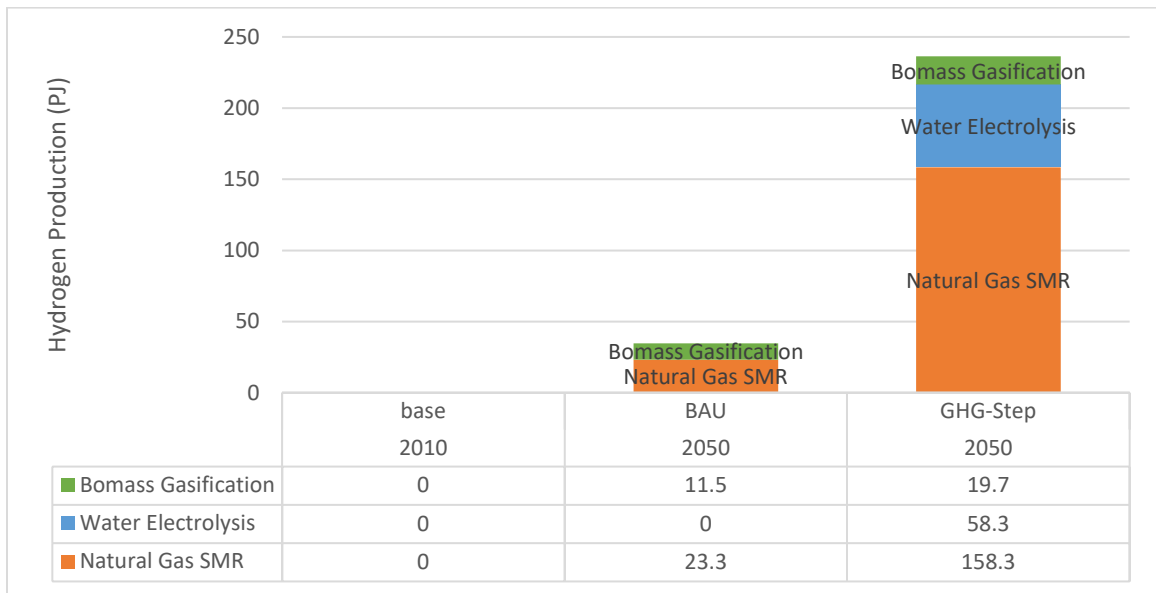
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Figure S6: CA-TIMES' crude oil supply and refinery energy production by scenario.

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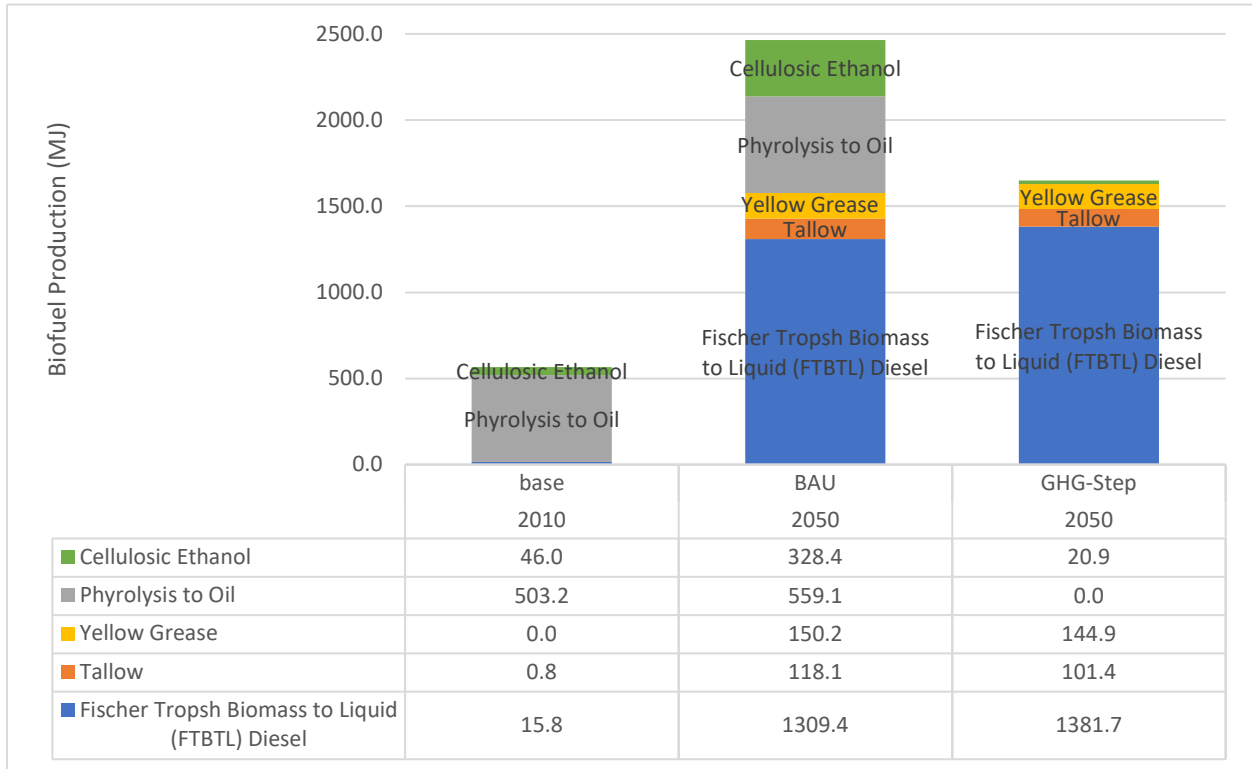


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Figure S7: CA-TIMES hydrogen production by process and scenario.

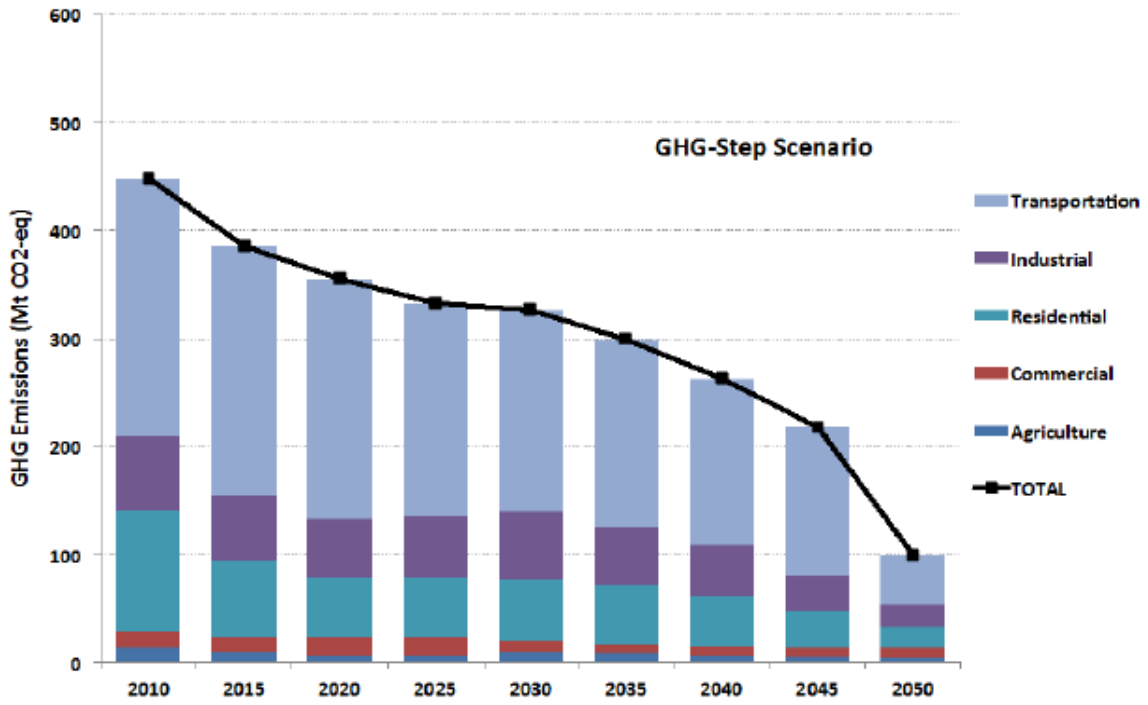
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40 **Figure S8: CA-TIMES' biofuel production by biofuel and scenario.**

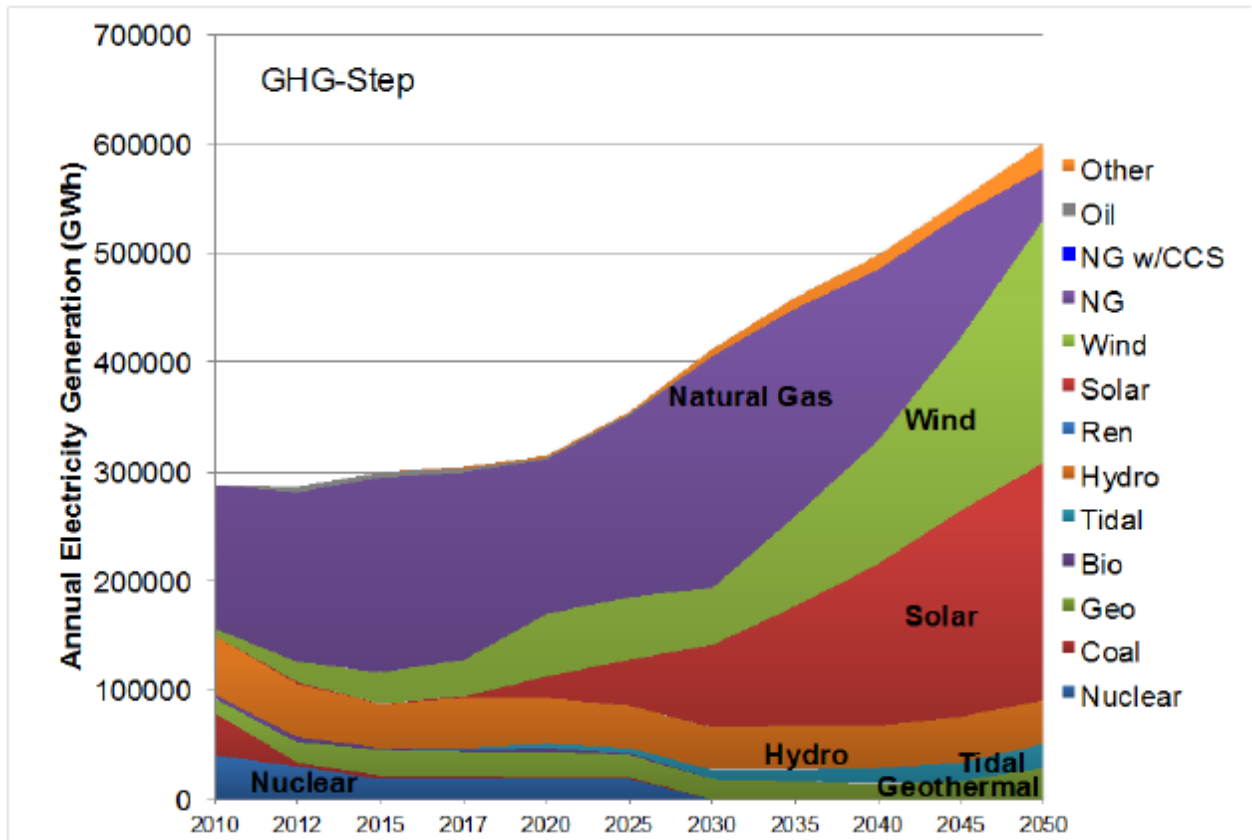
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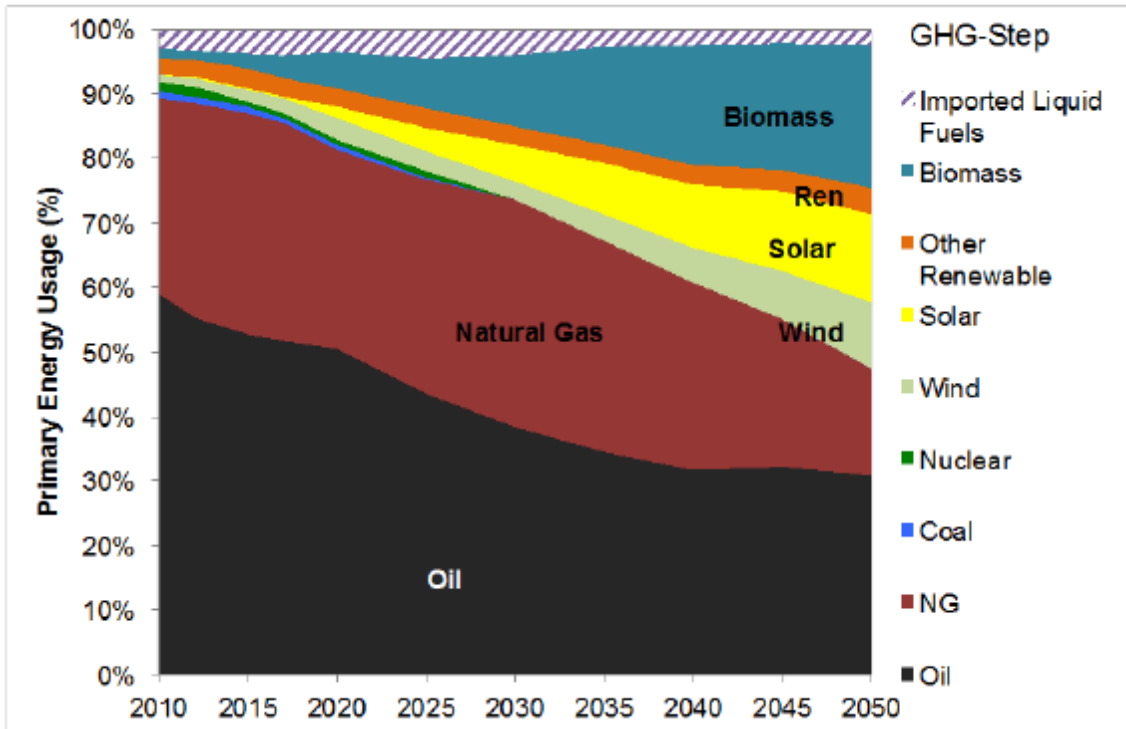
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44 Figure S9: Included Instate GHG emissions from 2010 to 2050 by sector for the GHG-Step scenario.
 45 (Yang, Yeh et al. 2014)

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48 Figure S.10: Electricity generation by resource type in the GHG-Step scenario. (Yang, Yeh et al. 2014)



50 Figure S.11: Annual share of primary energy resources for the GHG-Step scenario. (Yang, Yeh et al.
 51 2014)

52 **Table S1: EMFAC Geographic Area Index (GAI) county and air basin information.**

GAI	County	County Code	Air Basin	Air Basin/Air Management District Code
1	Alpine	2	Great Basin Valleys	GBV
2	Inyo	14	Great Basin Valleys	GBV
3	Mono	26	Great Basin Valleys	GBV
4	Lake	17	Lake County	LC
5	El Dorado	9	Lake Tahoe	LT
6	Placer	31	Lake Tahoe	LT
7	Amador	3	Mountain Counties	MC
8	Calaveras	5	Mountain Counties	MC
9	El Dorado	9	Mountain Counties	MC
10	Mariposa	22	Mountain Counties	MC
11	Nevada	29	Mountain Counties	MC
12	Placer	31	Mountain Counties	MC
13	Plumas	32	Mountain Counties	MC
14	Sierra	46	Mountain Counties	MC
15	Tuolumne	55	Mountain Counties	MC
16	Monterey	27	North Central Coast	NCC
17	San Benito	35	North Central Coast	NCC
18	Santa Cruz	44	North Central Coast	NCC
19	Del Norte	8	North Coast	NC
20	Humboldt	12	North Coast	NC
21	Mendocino	23	North Coast	NC
22	Sonoma	49	North Coast	NC
23	Trinity	53	North Coast	NC
24	Lassen	18	Northeast Plateau	NEP
25	Modoc	25	Northeast Plateau	NEP
26	Siskiyou	47	Northeast Plateau	NEP
27	Butte	4	Sacramento Valley	SV
28	Colusa	6	Sacramento Valley	SV
29	Glenn	11	Sacramento Valley	SV
30	Placer	31	Sacramento Valley	SV
31	Sacramento	34	Sacramento Valley	SV
32	Shasta	45	Sacramento Valley	SV
33	Solano	48	Sacramento Valley	SV
34	Sutter	51	Sacramento Valley	SV
35	Tehama	52	Sacramento Valley	SV
36	Yolo	57	Sacramento Valley	SV
37	Yuba	58	Sacramento Valley	SV

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55 **Table S1: EMFAC Geographic Area Index (GAI) county and air basin information (cont.).**

GAI	County	County Code	Air Basin	Air Basin/Air Management District Code
38	San Diego	37	San Diego	SD
39	Alameda	1	San Francisco Bay Area	SF
40	Contra Costa	7	San Francisco Bay Area	SF
41	Marin	21	San Francisco Bay Area	SF
42	Napa	28	San Francisco Bay Area	SF
43	San Francisco	38	San Francisco Bay Area	SF
44	San Mateo	41	San Francisco Bay Area	SF
45	Santa Clara	43	San Francisco Bay Area	SF
46	Solano	48	San Francisco Bay Area	SF
47	Sonoma	49	San Francisco Bay Area	SF
48	Fresno	10	San Joaquin Valley	SJV
49	Kern	15	San Joaquin Valley	SJV
50	Kings	16	San Joaquin Valley	SJV
51	Madera	20	San Joaquin Valley	SJV
52	Merced	24	San Joaquin Valley	SJV
53	San Joaquin	39	San Joaquin Valley	SJV
54	Stanislaus	50	San Joaquin Valley	SJV
55	Tulare	54	San Joaquin Valley	SJV
56	San Luis Obispo	40	South Central Coast	SCC
57	Santa Barbara	42	South Central Coast	SCC
58	Ventura	56	South Central Coast	SCC
59	Los Angeles	19	South Coast	SC
60	Orange	30	South Coast	SC
61	Riverside	33	South Coast	SC
62	San Bernardino	36	South Coast	SC
63	Imperial	13	Salton Sea	SS
64	Riverside	33	Salton Sea	SS
65	Kern	15	Mojave Desert	MD
66	Riverside	33	Mojave Desert	MD/MDAQMD
67	Riverside	33	Mojave Desert	MD/SCAQMD
68	Lassen	19	Mojave Desert	MD
69	San Bernardino	36	Mojave Desert	MD

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59 **Table S2: On-road mobile vehicle class codes/acronyms, fuels, and engine configurations in EMFAC and CA-TIMES.**

	EMFAC	CA-TIMES
Vehicle Class Categories	LDA – light duty passenger	CAR – passenger car
	LDT1 – light duty truck 1	LDT – light duty truck
	LDT2 – light duty truck 2	
	MDV – medium duty vehicle	MDT – medium duty truck
	LHDT1 – light-heavy duty truck 1	HDT – heavy duty truck
	LHDT2 – light-heavy duty truck 1	
	MHDT or T6 – medium-heavy duty truck or tier 6 truck	
	HHDT or T7 – heavy-heavy duty truck or tier 7	
	UBUS – urban or transit bus	BUST – transit bus
	SBUS – school bus	BUSS – school bus
	OBUS – other bus	BUSO – other bus
	MCY - motorcycle	MOT - motorcycle
	MH – motor home	Not available
	Fuels	GSL – gasoline
DSL - diesel		DSL – diesel
		MET – methanol
		BMET – biomass based methanol
		ETH – ethanol
		ETH85 – 85% ethanol 15% gasoline by volume blend
		NGA/CNG – compressed natural gas
		LPG – liquid petroleum gasoline
		BDL – biodiesel
		ELC – electricity
		GH2H – gaseous hydrogen
		GH2L – liquid hydrogen
Non-Conventional Vehicle Engine Configurations		
		X – bi-fuel
		HEV – hybrid electric vehicle
		PHEV – plug-in hybrid electric vehicle 10, 30, 40 electric miles
		ELC - battery electric
		FC – fuel cell

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62 **Table S3: On-road mobile 3-digit emission inventory codes (EICs) found in the 2010 emission inventory, and the new**
63 **EICs created for alternative fueled emissions, represented by the last 2 digits of the EICs ranging from 32-79. Emission**
64 **inventory codes (EICs) are typically 14 digits, XXX-XXX-XXXX-XXXX, where the dashes mark the full EIC into 4 parts,**
65 **EIC1, EIC2, EIC3, and EIC4 which each represent a different attribute of the source depending on the emission source**
66 **category.**

EIC (10s)			EIC (100s)						
EIC	EIC fuel	EIC emission process	200s	300s	400s	500s	600s	700s	800s
			LDA, LDT, MDV, MH, MCY, OBUS , SBUS	LHDT , MHD T, HHD V, UBUS	HHDT	MHD T	OBUS	UBUS	LDA, LDT, MDV, MH, MCY, LHDT
2-7, 9-10, 15-16, 18-19	gasoline	catalyst/non-catalyst cold/hot exhaust, hot soak, diurnal, running/resting evaporative, idle	X	X					
8, 17, 20	diesel	exhaust, idle			X	X	X	X	X
13, 14	gasoline, diesel	tire, break wear	X	X	X	X	X	X	X
32-37, 39-40, 45-46, 48-49	E85	catalyst/non-catalyst cold/hot exhaust, hot soak, diurnal, running/resting evaporative, idle	X	X					
38, 47, 50	biodiesel	exhaust, idle			X	X	X	X	X
43, 44	E85, biodiesel	tire, break wear	X	X	X	X	X	X	X
62-67, 69-70, 75-76, 78-79	CNG	catalyst/non-catalyst cold/hot exhaust, hot soak, diurnal, running/resting evaporative, idle	X	X					
73, 74	CNG	tire, break wear	X	X	X	X	X	X	X

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Table S4: Passenger car vehicle class CA-TIMES codes, fuels, engine configurations and assigned indices.

Vehicle index	Class index	Fuel index	Tech index	Vehicle Code	Fleet class	Fuel	Tech	Description
1	1	1	1	TCARAGSL	CAR	GSL	A	Passenger Car -- Advanced Gasoline
2	1	1	1	TCARGSL	CAR	GSL		Passenger Car -- Gasoline
3	1	1	1	TCARGSL05	CAR	GSL		Base Year - Light-duty Passenger Car (Gasoline)
4	1	1	1	TCARMGSL	CAR	GSL	M	Passenger Car -- Moderate Gasoline
5	1	1	7	TCARGSLHEV	CAR	GSL	HEV	Passenger Car -- Gasoline HEV
6	1	1	7	TCARGSLHEV05	CAR	GSL	HEV	Base Year - Light-duty Passenger Car (Gasoline HEV)
7	1	1	8	TCARGSLPHEV10	CAR	GSL	PHEV	Passenger Car -- Gasoline PHEV10
8	1	1	8	TCARGSLPHEV30	CAR	GSL	PHEV	Passenger Car -- Gasoline PHEV30
9	1	1	8	TCARGSLPHEV40	CAR	GSL	PHEV	Passenger Car -- Gasoline PHEV40
10	1	1	8	TCARGSLPHEV60	CAR	GSL	PHEV	Passenger Car -- Gasoline PHEV60
11	1	1	10	TCARFCGSL	CAR	GSL	FC	Passenger Car -- Gasoline Fuel Cell
12	1	2	1	TCARDSL	CAR	DSL		Passenger Car -- Diesel
13	1	2	1	TCARDSL05	CAR	DSL		Base Year - Light-duty Passenger Car (Diesel)
14	1	2	7	TCARDSLHEV	CAR	DSL	HEV	Passenger Car -- Diesel HEV
15	1	2	8	TCARDSLPHEV10	CAR	DSL	PHEV	Passenger Car -- Diesel PHEV10
16	1	2	8	TCARDSLPHEV30	CAR	DSL	PHEV	Passenger Car -- Diesel PHEV30
17	1	2	8	TCARDSLPHEV40	CAR	DSL	PHEV	Passenger Car -- Diesel PHEV40
18	1	2	8	TCARDSLPHEV60	CAR	DSL	PHEV	Passenger Car -- Diesel PHEV60
19	1	3	10	TCARFCMETH	CAR	METH	FC	Passenger Car -- Methanol Fuel Cell
20	1	5	1	TCARETH	CAR	ETH		Passenger Car -- Dedicated Ethanol
21	1	6	3	TCARAE85	CAR	E85	A	Passenger Car -- Advanced E85 Flex Fuel
22	1	6	3	TCARE85	CAR	E85		Passenger Car -- E85 Flex Fuel
23	1	6	3	TCARME85	CAR	E85	M	Passenger Car -- Moderate E85 Flex Fuel
24	1	6	4	TCARE85HEV	CAR	E85	HEV	Passenger Car -- E85 Flex Fuel HEV
25	1	6	5	TCARE85PHEV10	CAR	E85	PHEV	Passenger Car -- E85 Flex Fuel PHEV10
26	1	6	5	TCARE85PHEV30	CAR	E85	PHEV	Passenger Car -- E85 Flex Fuel PHEV30
27	1	6	5	TCARE85PHEV40	CAR	E85	PHEV	Passenger Car -- E85 Flex Fuel PHEV40
28	1	6	5	TCARE85PHEV60	CAR	E85	PHEV	Passenger Car -- E85 Flex Fuel PHEV60
29	1	7	1	TCARCNG	CAR	CNG		Passenger Car -- Natural Gas
30	1	7	6	TCARCNGX	CAR	CNG		Passenger Car -- Natural Gas Bi-Fuel
31	1	8	1	TCARLPG	CAR	LPG		Passenger Car -- LPG
32	1	8	6	TCARLPGX	CAR	LPG		Passenger Car -- LPG Bi-Fuel
33	1	10	9	TCARELC	CAR	ELC		Passenger Car -- Electric
34	1	10	9	TCARELC1	CAR	ELC		Passenger Car -- Electric
35	1	10	9	TCARELC2	CAR	ELC		Passenger Car -- Electric
36	1	10	9	TCARELC05	CAR	ELC		Base Year - Light-duty Passenger Car (Electric)
37	1	11	10	TCARFCH2	CAR	H2	FC	Passenger Car -- Hydrogen Fuel Cell

Table S5: Light duty truck vehicle class CA-TIMES codes, fuels, engine configurations and assigned indices.

Vehicle Index	Class index	Fuel index	Tech index	Vehicle Code	Fleet class	Fuel	Tech	Description
38	2	1	1	TLDTAGSL	LDT	GSL	A	Light-duty Truck -- Advanced Gasoline
39	2	1	1	TLDTAGSL	LDT	GSL	A	Light-duty Truck -- Advanced Gasoline
40	2	1	1	TLDTGSL	LDT	GSL		Light-duty Truck -- Gasoline
41	2	1	1	TLDTGSL	LDT	GSL		Light-duty Truck -- Gasoline
42	2	1	1	TLDTGSL05	LDT	GSL		Base Year - Light-duty Truck (Gasoline)
43	2	1	1	TLDTGSL05	LDT	GSL		Base Year - Light-duty Truck (Gasoline)
44	2	1	1	TLDTMGSL	LDT	GSL	M	Light-duty Truck -- Moderate Gasoline
45	2	1	1	TLDTMGSL	LDT	GSL	M	Light-duty Truck -- Moderate Gasoline
46	2	1	7	TLDTGSLHEV	LDT	GSL	HEV	Light-duty Truck -- Gasoline HEV
47	2	1	7	TLDTGSLHEV	LDT	GSL	HEV	Light-duty Truck -- Gasoline HEV
48	2	1	7	TLDTGSLHEV05	LDT	GSL	HEV	Base Year - Light-duty Truck (Gasoline HEV)
49	2	1	7	TLDTGSLHEV05	LDT	GSL	HEV	Base Year - Light-duty Truck (Gasoline HEV)
50	2	1	8	TLDTGSLPHEV10	LDT	GSL	PHEV	Light-duty Truck -- Gasoline PHEV10
51	2	1	8	TLDTGSLPHEV10	LDT	GSL	PHEV	Light-duty Truck -- Gasoline PHEV10
52	2	1	8	TLDTGSLPHEV30	LDT	GSL	PHEV	Light-duty Truck -- Gasoline PHEV30
53	2	1	8	TLDTGSLPHEV30	LDT	GSL	PHEV	Light-duty Truck -- Gasoline PHEV30
54	2	1	8	TLDTGSLPHEV40	LDT	GSL	PHEV	Light-duty Truck -- Gasoline PHEV40
55	2	1	8	TLDTGSLPHEV40	LDT	GSL	PHEV	Light-duty Truck -- Gasoline PHEV40
56	2	1	8	TLDTGSLPHEV60	LDT	GSL	PHEV	Light-duty Truck -- Gasoline PHEV60
57	2	1	8	TLDTGSLPHEV60	LDT	GSL	PHEV	Light-duty Truck -- Gasoline PHEV60
58	2	1	10	TLDTFCGSL	LDT	GSL	FC	Light-duty Truck -- Gasoline Fuel Cell
59	2	2	1	TLDTDSL	LDT	DSL		Light-duty Truck -- Diesel
60	2	2	1	TLDTDSL	LDT	DSL		Light-duty Truck -- Diesel
61	2	2	1	TLDTDSL05	LDT	DSL		Base Year - Light-duty Truck (Diesel)
62	2	2	1	TLDTDSL05	LDT	DSL		Base Year - Light-duty Truck (Diesel)
63	2	2	7	TLDTDSLHEV	LDT	DSL	HEV	Light-duty Truck -- Diesel HEV
64	2	2	7	TLDTDSLHEV	LDT	DSL	HEV	Light-duty Truck -- Diesel HEV
65	2	2	8	TLDTDSL PHEV10	LDT	DSL	PHEV	Light-duty Truck -- Diesel PHEV10
66	2	2	8	TLDTDSL PHEV10	LDT	DSL	PHEV	Light-duty Truck -- Diesel PHEV10
67	2	2	8	TLDTDSL PHEV30	LDT	DSL	PHEV	Light-duty Truck -- Diesel PHEV30
68	2	2	8	TLDTDSL PHEV30	LDT	DSL	PHEV	Light-duty Truck -- Diesel PHEV30
69	2	2	8	TLDTDSL PHEV40	LDT	DSL	PHEV	Light-duty Truck -- Diesel PHEV40
70	2	2	8	TLDTDSL PHEV40	LDT	DSL	PHEV	Light-duty Truck -- Diesel PHEV40
71	2	2	8	TLDTDSL PHEV60	LDT	DSL	PHEV	Light-duty Truck -- Diesel PHEV60
72	2	2	8	TLDTDSL PHEV60	LDT	DSL	PHEV	Light-duty Truck -- Diesel PHEV60

76 **Table S6: Light duty truck vehicle class CA-TIMES codes, fuels, engine configurations and assigned indices (continued).**

Vehicle Index	Class index	Fuel index	Tech index	Vehicle Code	Fleet class	Fuel	Tech	Description
73	2	3	10	TLDTFCMETH	LDT	METH	FC	Light-duty Truck -- Methanol Fuel Cell
74	2	5	1	TLDTETH	LDT	ETH		Light-duty Truck -- Dedicated Ethanol
75	2	6	3	TLDTAE85	LDT	E85	A	Light-duty Truck -- Advanced E85 Flex Fuel
76	2	6	3	TLDTE85	LDT	E85		Light-duty Truck -- E85 Flex Fuel
77	2	6	3	TLDTME85	LDT	E85	M	Light-duty Truck -- Moderate E85 Flex Fuel
78	2	6	4	TLDTE85HEV	LDT	E85	HEV	Light-duty Truck -- E85 Flex Fuel HEV
79	2	6	5	TLDTE85PHEV10	LDT	E85	PHEV	Light-duty Truck -- E85 Flex Fuel PHEV10
80	2	6	5	TLDTE85PHEV30	LDT	E85	PHEV	Light-duty Truck -- E85 Flex Fuel PHEV30
81	2	6	5	TLDTE85PHEV40	LDT	E85	PHEV	Light-duty Truck -- E85 Flex Fuel PHEV40
82	2	6	5	TLDTE85PHEV60	LDT	E85	PHEV	Light-duty Truck -- E85 Flex Fuel PHEV60
83	2	7	1	TLDTCNG	LDT	CNG		Light-duty Truck -- Natural Gas
84	2	7	6	TLDTCNGX	LDT	CNG		Light-duty Truck -- Natural Gas Bi-Fuel
85	2	8	1	TLDTLPG	LDT	LPG		Light-duty Truck -- LPG
86	2	8	6	TLDTLPGX	LDT	LPG		Light-duty Truck -- LPG Bi-Fuel
87	2	10	9	TLDTELC	LDT	ELC		Light-duty Truck -- Electric
88	2	10	9	TLDTELC1	LDT	ELC		Light-duty Truck -- Electric
89	2	10	9	TLDTELC2	LDT	ELC		Light-duty Truck -- Electric
90	2	11	10	TLDTFCH2	LDT	H2	FC	Light-duty Truck -- Hydrogen Fuel Cell

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78 **Table S7: Medium-duty truck vehicle class CA-TIMES codes, fuels, engine configurations and assigned indices.**

Vehicle Index	Class index	Fuel index	Tech index	Vehicle Code	Fleet class	Fuel	Tech	Description
91	3	1	1	TMDTGSL	MDT	GSL		Medium-duty Truck -- Gasoline
92	3	1	1	TMDTGSL05	MDT	GSL		Base Year - Medium-duty Truck (Gasoline)
93	3	1	7	TMDTGSLHEV	MDT	GSL	HEV	Medium-duty Truck -- Gasoline HEV
94	3	1	8	TMDTGSLPHEV30	MDT	GSL	PHEV	Medium-duty Truck -- Gasoline PHEV30
95	3	2	1	TMDTDSL	MDT	DSL		Medium-duty Truck -- Diesel
96	3	2	1	TMDTDSL05	MDT	DSL		Base Year - Medium-duty Truck (Diesel)
97	3	2	7	TMDTDSLHEV	MDT	DSL	HEV	Medium-duty Truck -- Diesel HEV
98	3	2	8	TMDTDSL PHEV30	MDT	DSL	PHEV	Medium-duty Truck -- Diesel PHEV30
99	3	5	1	TMDTETH	MDT	ETH		Medium-duty Truck -- Dedicated Ethanol (E95)
100	3	7	1	TMDTCNG	MDT	CNG		Medium-duty Truck -- Compressed Natural Gas
101	3	7	7	TMDTCNGHEV	MDT	CNG	HEV	Medium-duty Truck -- Compressed Natural Gas HEV
102	3	7	8	TMDTCNGPHEV30	MDT	CNG	PHEV	Medium-duty Truck -- Compressed Natural Gas PHEV30
103	3	8	1	TMDTLPG	MDT	LPG		Medium-duty Truck -- LPG
104	3	11	7	TMDTH2HEV	MDT	H2	HEV	Medium-duty Truck -- Hydrogen ICE-HEV
105	3	11	10	TMDTFCH2	MDT	H2	FC	Medium-duty Truck -- Hydrogen Fuel Cell

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80 **Table S8: Heavy-duty truck vehicle class CA-TIMES codes, fuels, engine configurations and assigned indices.**

Vehicle Index	Class index	Fuel index	Tech index	Vehicle Code	Fleet class	Fuel	Tech	Description
106	4	1	1	THDTGSL	HDT	GSL		Heavy-duty Truck -- Gasoline
107	4	1	1	THDTGSL05	HDT	GSL		Base Year - Heavy-duty Truck (Gasoline)
108	4	2	1	THDTDSL	HDT	DSL		Heavy-duty Truck -- Diesel
109	4	2	1	THDTDSL05	HDT	DSL		Base Year - Heavy-duty Truck (Diesel)
110	4	2	2	THDTDSL10P	HDT	DSL	10P	Heavy-duty Truck -- Diesel +10% EFF
111	4	2	2	THDTDSL20P	HDT	DSL	20P	Heavy-duty Truck -- Diesel +20% EFF
112	4	2	2	THDTDSL40P	HDT	DSL	40P	Heavy-duty Truck -- Diesel +40% EFF
113	4	3	1	THDTM95	HDT	M95		Heavy-duty Truck -- Dedicated Methanol (M95)
114	4	5	1	THDTETH	HDT	ETH		Heavy-duty Truck -- Dedicated Ethanol (E95)
115	4	7	1	THDTCNG	HDT	CNG		Heavy-duty Truck -- Compressed Natural Gas
116	4	8	1	THDTLPG	HDT	LPG		Heavy-duty Truck -- LPG

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Table S9: Transit bus vehicle class CA-TIMES codes, fuels, engine configurations and assigned indices.

Vehicle Index	Class index	Fuel index	Tech index	Vehicle Code	Fleet class	Fuel	Tech	Description
117	5	1	1	TBUSTGSL	BUST	GSL		Transit Bus -- Gasoline
118	5	1	1	TBUSTGSL05	BUST	GSL		Base Year - Transit Bus (Gasoline)
119	5	1	2	TBUSTGSL20P	BUST	GSL	20P	Transit Bus -- Gasoline +20% EFF
120	5	1	2	TBUSTGSL40P	BUST	GSL	40P	Transit Bus -- Gasoline +40% EFF
121	5	1	8	TBUSTGSLPHEV30	BUST	GSL	PHEV	Transit Bus -- Gasoline PHEV30
122	5	2	1	TBUSTDSL	BUST	DSL		Transit Bus -- Diesel
123	5	2	1	TBUSTDSL05	BUST	DSL		Base Year - Transit Bus (Diesel)
124	5	2	2	TBUSTDSL20P	BUST	DSL	20P	Transit Bus -- Diesel +20% EFF
125	5	2	2	TBUSTDSL40P	BUST	DSL	40P	Transit Bus -- Diesel +40% EFF
126	5	2	7	TBUSTDSLHEV	BUST	DSL	HEV	Transit Bus -- Diesel HEV
127	5	2	8	TBUSTDSLPH30	BUST	DSL	PHEV	Transit Bus -- Diesel PHEV30
128	5	3	1	TBUSTM95	BUST	M95		Transit Bus -- Dedicated Methanol (M95)
129	5	5	1	TBUSTETH	BUST	ETH		Transit Bus -- Dedicated Ethanol (E95)
130	5	7	1	TBUSTCNG	BUST	CNG		Transit Bus -- Compressed Natural Gas
131	5	7	1	TBUSTCNG05	BUST	CNG		Base Year - Transit Bus (Compressed Natural Gas)
132	5	7	7	TBUSTCNGHEV	BUST	CNG	HEV	Transit Bus -- Compressed Natural Gas HEV
133	5	7	8	TBUSTCNGPHEV30	BUST	CNG	PHEV	Transit Bus -- Compressed Natural Gas PHEV30
134	5	8	1	TBUSTLPG	BUST	LPG		Transit Bus -- LPG
135	5	10	9	TBUSTELC	BUST	ELC		Transit Bus -- Electric
136	5	10	9	TBUSTELC05	BUST	ELC		Base Year - Transit Bus (Electric)
137	5	11	7	TBUSTH2HEV	BUST	H2	HEV	Transit Bus -- Hydrogen ICE-HEV
138	5	11	10	TBUSTFCH2	BUST	H2	FC	Transit Bus -- Hydrogen Fuel Cell

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Table S10: School bus vehicle class CA-TIMES codes, fuels, engine configurations and assigned indices.

Vehicle Index	Class index	Fuel index	Tech index	Vehicle Code	Fleet class	Fuel	Tech	Description
139	6	1	1	TBUSSGSL	BUSS	GSL		School Bus -- Gasoline
140	6	1	1	TBUSSGSL05	BUSS	GSL		Base Year - School Bus (Gasoline)
141	6	1	2	TBUSSGSL20P	BUSS	GSL	20P	School Bus -- Gasoline +20% EFF
142	6	1	2	TBUSSGSL40P	BUSS	GSL	40P	School Bus -- Gasoline +40% EFF
143	6	1	8	TBUSSGSLPHEV30	BUSS	GSL	PHEV	School Bus -- Gasoline PHEV30
144	6	2	1	TBUSSDSL	BUSS	DSL		School Bus -- Diesel
145	6	2	1	TBUSSDSL05	BUSS	DSL		Base Year - School Bus (Diesel)
146	6	2	2	TBUSSDSL20P	BUSS	DSL	20P	School Bus -- Diesel +20% EFF
147	6	2	2	TBUSSDSL40P	BUSS	DSL	40P	School Bus -- Diesel +40% EFF
148	6	2	7	TBUSSDSLHEV	BUSS	DSL	HEV	School Bus -- Diesel HEV
149	6	2	8	TBUSSDSL PHEV30	BUSS	DSL	PHEV	School Bus -- Diesel PHEV30
150	6	3	1	TBUSSM95	BUSS	M95		School Bus -- Dedicated Methanol (M95)
151	6	5	1	TBUSSETH	BUSS	ETH		School Bus -- Dedicated Ethanol (E95)
152	6	7	1	TBUSSCNG	BUSS	CNG		School Bus -- Compressed Natural Gas
153	6	7	7	TBUSSCNGHEV	BUSS	CNG	HEV	School Bus -- Compressed Natural Gas HEV
154	6	7	8	TBUSSCNGPHEV30	BUSS	CNG	PHEV	School Bus -- Compressed Natural Gas PHEV30
155	6	8	1	TBUSSLPG	BUSS	LPG		School Bus -- LPG
156	6	10	9	TBUSSELC	BUSS	ELC		School Bus -- Electric
157	6	11	7	TBUSSH2HEV	BUSS	H2	HEV	School Bus -- Hydrogen ICE-HEV
158	6	11	10	TBUSSFCH2	BUSS	H2	FC	School Bus -- Hydrogen Fuel Cell

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87 **Table S11: Other bus vehicle class CA-TIMES codes, fuels, engine configurations and assigned indices.**

Vehicle Index	Class index	Fuel index	Tech index	Vehicle Code	Fleet class	Fuel	Tech	Description
159	7	1	1	TBUSOGSL	BUSO	GSL		Intercity or Other Bus -- Gasoline
160	7	1	1	TBUSOGSL05	BUSO	GSL		Base Year - Intercity or Other Bus (Gasoline)
161	7	1	2	TBUSOGSL20P	BUSO	GSL	20P	Intercity or Other Bus -- Gasoline +20% EFF
162	7	1	2	TBUSOGSL40P	BUSO	GSL	40P	Intercity or Other Bus -- Gasoline +40% EFF
163	7	1	8	TBUSOGSLPHEV30	BUSO	GSL	PHEV	Intercity or Other Bus -- Gasoline PHEV30
164	7	2	1	TBUSODSL	BUSO	DSL		Intercity or Other Bus -- Diesel
165	7	2	1	TBUSODSL05	BUSO	DSL		Base Year - Intercity or Other Bus (Diesel)
166	7	2	2	TBUSODSL20P	BUSO	DSL	20P	Intercity or Other Bus -- Diesel +20% EFF
167	7	2	2	TBUSODSL40P	BUSO	DSL	40P	Intercity or Other Bus -- Diesel +40% EFF
168	7	2	7	TBUSODSLHEV	BUSO	DSL	HEV	Intercity or Other Bus -- Diesel HEV
169	7	2	8	TBUSODSLPHEV30	BUSO	DSL	PHEV	Intercity or Other Bus -- Diesel PHEV30
170	7	3	1	TBUSOM95	BUSO	M95		Intercity or Other Bus -- Dedicated Methanol (M95)
171	7	5	1	TBUSOETH	BUSO	ETH		Intercity or Other Bus -- Dedicated Ethanol (E95)
172	7	7	1	TBUSOCNG	BUSO	CNG		Intercity or Other Bus -- Compressed Natural Gas
173	7	7	7	TBUSOCNGHEV	BUSO	CNG	HEV	Intercity or Other Bus -- Compressed Natural Gas HEV
174	7	7	8	TBUSOCNGPHEV30	BUSO	CNG	PHEV	Intercity or Other Bus -- Compressed Natural Gas PHEV30
175	7	8	1	TBUSOLPG	BUSO	LPG		Intercity or Other Bus -- LPG
176	7	10	9	TBUSOELC	BUSO	ELC		Intercity or Other Bus -- Electric
177	7	11	7	TBUSOH2HEV	BUSO	H2	HEV	Intercity or Other Bus -- Hydrogen ICE-HEV
178	7	11	10	TBUSOFCH2	BUSO	H2	FC	Intercity or Other Bus -- Hydrogen Fuel Cell

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89 **Table S12: Motorcycle vehicle class CA-TIMES codes, fuels, engine configurations and assigned indices.**

Vehicle Index	Class index	Fuel index	Tech index	Vehicle Code	Fleet class	Fuel	Tech	Description
179	8	1	1	TMOTGSL	MOT	GSL		Motorcycle -- Gasoline
180	8	1	1	TMOTGSL05	MOT	GSL		Base Year - Motorcycle (Gasoline)
181	8	5	1	TMOTETH	MOT	ETH		Motorcycle -- Dedicated Ethanol (E95)

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92 Table S13: New emission particulate source profiles created. Where X is the beginning of the EIC digit from 2-8 based on
 93 vehicle weight class as listed in Table S3. Dashes are vehicle, equipment, or vessel subcategories and other groupings
 94 listed in tables for that emission source category (EIC) in Table S3 through Table .

Source Category	Fuel, Aftertreatment Device	Acronym	PM Profile #	Gaseous Profile #	New Assigned EIC3 Fuel Classification	EICs
Vehicular, Off-road, recreational boats	Flex-fueled vehicle consuming ethanol 85% by volume; ethanol 95% by volume	E85FFV or E95	095	0891 (hot start), 0893 (cold start)	N/A	X31-X37, X39-X42, X45-X46, X48-X49, X51
Vehicular	Biodiesel with exhaust gas recirculation, selective catalytic reduction, diesel particulate filter, diesel oxidation catalyst	BDL+ EGR+ SCR+ DPF+ DOC	096	0895	N/A	X38, X47, X50
Vehicular	Compressed natural gas with three-way catalyst	CNG+TWC	097	0894	N/A	X61-X72, X75-X81, X75-X81
Off-road/ agricultural equipment, marine vessels, trains	Biodiesel	BDL	098	0818	2210	860 ___ 2210 ___ 870 ___ 2210 ___
Aviation	Bio-jet fuel	BAJF	099	0413	2140	810 ___ 2140 ___
Marine	Bio-residual oil	BRDO	172	0504	2500	833 ___ 2500 ___

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Table S14: Total organic gas (TOG) mass fraction species profile for alternative fuels.

Alternative Fuel		E6	E6	E85	E85	CNG
Emission Process		Cold Start	Exhaust	Cold Start	Exhaust	Exhaust
Species Index	SAPRC 2011 Species	TOG Mass Fraction				
1	CH4	1.570E-01	3.050E-01	2.312E-01	3.579E-01	9.987E-01
2	ALK1	3.454E-02	4.894E-02	2.586E-02	2.731E-02	0.000E+00
3	ALK2	1.727E-02	2.487E-02	6.501E-03	1.618E-02	0.000E+00
4	ALK3	1.353E-02	2.012E-02	1.741E-02	7.561E-03	0.000E+00
5	ALK4	2.224E-01	2.196E-01	8.570E-02	7.335E-02	0.000E+00
6	ALK5	8.378E-02	8.530E-02	3.812E-02	3.526E-02	0.000E+00
7	ETHENE	8.301E-02	6.246E-02	7.085E-02	4.941E-02	0.000E+00
8	OLE1	5.778E-02	4.058E-02	1.492E-02	5.612E-03	1.796E-06
9	OLE2	8.674E-02	7.499E-02	4.493E-02	5.168E-02	0.000E+00
10	ISOPRENE	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
11	TERP	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
12	BENZENE	1.989E-02	1.539E-02	5.141E-03	2.708E-03	2.599E-05
13	ARO1	5.404E-02	8.347E-02	2.411E-02	4.594E-02	0.000E+00
14	ARO2	6.760E-02	7.366E-02	2.283E-02	3.235E-02	0.000E+00
15	ACETYLEN	3.843E-02	1.843E-02	2.257E-02	1.718E-02	0.000E+00
16	HCHO	5.407E-03	9.815E-03	9.031E-03	1.234E-02	3.251E-05
17	CCHO	4.293E-03	8.472E-03	3.941E-02	6.113E-02	2.366E-05
18	RCHO	1.106E-03	2.596E-03	8.168E-04	1.723E-03	1.058E-04
19	BALD	2.707E-04	7.548E-04	8.549E-05	4.885E-04	7.886E-06
20	ACET	3.461E-03	7.853E-03	1.730E-03	3.625E-03	6.434E-04
21	MEK	1.744E-03	3.266E-03	1.757E-03	1.265E-03	1.923E-06
22	PROD2	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
23	MEOH	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
24	HCOOH	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
25	CCOOH	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
26	RCOOH	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
27	GLY	6.908E-05	2.391E-04	6.399E-05	2.329E-04	0.000E+00
28	MGLY	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
29	BACL	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
30	CRES	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
31	PHEN	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
32	XYNL	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
33	CATL	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
34	MACR	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
35	MVK	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
36	IPRD	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
37	RNO3	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
38	ETOH	2.806E-02	1.849E-02	3.369E-01	1.968E-01	4.302E-04
39	NMOG	6.682E-01	5.971E-01	5.737E-01	4.709E-01	1.273E-03

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102 **Table S15: Particle size distribution change by bin or radius for various alternative fuels.**

Alternative Fuel		E0	E85	B100	CNG
Aftertreatment		TWC	TWC	DPF + EGR	TWC
Bin	Particle	Particle Mass Fraction			
Number	Radius, Rp Bin Midpoint (nm)				
1	6.3	0.0096	0.0719	0.0021	0.0307
2	10.0	0.0205	0.1682	0.0028	0.0380
3	16.0	0.0615	0.2235	0.0104	0.0589
4	25.0	0.0854	0.2827	0.0301	0.0817
5	39.5	0.1886	0.1911	0.0650	0.0999
6	63.0	0.2820	0.0566	0.1770	0.1454
7	100.0	0.2728	0.0061	0.4593	0.2529
8	160.0	0.0737	0.0000	0.2534	0.1837
9	250	0.0059	0.0000	0.0000	0.1088
10	395	0.0000	0.0000	0.0000	0.0000
11	630	0.0000	0.0000	0.0000	0.0000
12	1000	0.0000	0.0000	0.0000	0.0000
13	1600	0.0000	0.0000	0.0000	0.0000
14	2500	0.0000	0.0000	0.0000	0.0000
15	3950	0.0000	0.0000	0.0000	0.0000

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105 **Table S16: Inorganic PM mass fraction exhaust profiles for updated and alternative fuels.**

Element	E85	DSL	DSL+DPF	CNG
EC	0.053164	0.177707	0.000882	0.218562
OC	0.844468	0.044608	0.014997	0.389125
SO4	-	0.000635	0.002941	0.023468
NO3	-	0.003445	0.002352	0.245907
NH4	-	0.000181	0.000588	0.005102
Al	0.000818	0.001342	0.000606	0.000331
Ca	0.010864	0.136907	0.020172	0.022856
Fe	0.037773	0.000047	0.000294	-
Mg	-	0.046240	0.007645	0.001656
Na	-	0.160480	0.005058	0.018367
P	0.002773	0.041616	0.007469	0.045916
S	0.011136	0.222134	0.905690	-
K	0.002500	0.093387	0.013527	0.015305
V	-	0.000343	0.000029	-
Cr	0.000227	0.003092	0.001988	-
Mn	0.000091	0.001124	0.001038	-
Co	-	0.000052	0.000084	-
Ni	0.000818	0.001451	0.003058	-
Cu	0.000364	0.000062	0.000202	0.000331
Zn	0.000455	0.063648	0.010939	0.000828
Cd	-	0.000047	0.000024	-
Ba	-	0.001287	0.000347	-
Br	0.010591	-	-	-
Pb	0.000273	0.000165	0.000070	-
Si	0.009545	-	-	-
Cl	-	-	0.012244	-
Other	0.014141	-	-	-

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108 **Table S17: Aviation, rail, and off-road EICs.**

EIC1 - Category		EIC2 - Type		EIC3 - fuel	
860	Off-road equipment	883	Lawn equipment	1210	Diesel
		884	Transport refrigeration unit (TRU)	1100	Gasoline
		885	Light commercial equipment	0110	Natural Gas
		886	Industrial equipment	2210	Biodiesel
		887	Construction and mining equipment	2195	E95
		888	Logging equipment		
		889	Airport ground		
		890	Dredging		
		891	Oil drilling		
		892	Military equipment		
		894	Entertainment		
		896	Port operations		
		897	Rail operations		
		901-903	Lawn equipment		
		904-906	Commercial		
		995	Other commercial		
850	Recreational vehicles	870	Snowmobiles	1100	Gasoline
		871	Recreational equipment	2195	E95
		872	Off-road motorcycles		
		873	Minibikes		
		874	ATVs		
		875	Golf carts		
		877	Vehicle carts		
870	Farming Equipment	893	Agricultural equipment	1210	Diesel
				1100	Gasoline
				2210	Biodiesel
				2195	E95
810	Aircraft	802, 810	Commercial	1140	Aviation gasoline
		804, 812	Civil	1400	Jet fuel
		806	Agricultural	2140	Biomass-based aviation gasoline
		800, 808	Military	2400	Biomass-based jet fuel

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113 **Table S18: Aviation fossil and jet fuel PM size distribution changes.**

Bin Index	Midpoint (nm)	Jet A Mass Frac	GTL Mass Frac
1	6.3	0	0
2	10	0	0
3	16	0	0
4	25	0.016	0.046
5	39.5	0.298	0.399
6	63	0.279	0.114
7	100	0.059	0.058
8	160	0.108	0.107
9	250	0.147	0.155
10	395	0.065	0.080
11	630	0.024	0.036
12	1000	0.005	0.005
13	1600	0	0
14	2500	0	0
15	3950	0	0

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116 **Table S19: Marine source EICs.**

Category (EIC1, 3 digits)		EIC2 - Type		EIC3 - fuel	
833	Ocean going vessels (OGV)	831	Auto Carriers	1210	Diesel
		833	Bulk cargo	1500	Residual oil
		835	Container	2210	Biodiesel
		837	General Cargo	2500	Biomass-based Residual oil
		841	Passenger (cruise)		
		843	Reefers (Refrigerated cargo)		
		845	Roll on/roll off (Ro-Ro)		
		847	Tankers		
		849	Miscellaneous		
		861	Military		
835	Commercial harbor craft (CHC)	851	Crew and Supply	1210	Diesel
		853	Excursion Vessels	2210	Biodiesel
		855	Ferries		
		857	Fishing		
		861	Military		
		862	Other		
		863	Pilot vessels		
		865	Tow boats		
		866	Tug boats		
867	Work boats				
840	Boats	864	Recreational boats	1210	Diesel
				1100	Gasoline
				2210	Biodiesel
				2195	E95

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119 Table S20: Extrapolated growth rate beyond 2020 projections (Starcrest Consulting Group 2009, The Port of Los Angeles
 120 and The Port of Long Beach 2010) by marine vessel type or purpose.

Marine Vessel Type	2050:2010 Growth Rate
Container	5.971
Auto Carrier	2.827
Bulk Cargo	2.524
Cruise/Passenger	2.053
General Cargo	3.593
Reefer/Refrigeration	2.393
Roll On/Roll Off	2.827
Tanker	2.253

121
 122 Table S21: Berthing or hoteling scaling factor applied only to hoteling, passenger, and reefer running on auxiliary power
 123 emission reductions based on on-shore electrification ruling.

	Fraction remaining	Efficiency
CO	0.3	70%
NOx	0.3	70%
SOx	0.3	70%
ROG	0.3	70%
PM	0.3	70%

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 125 Table S22: SOx emission reduction scaling factor based on 24 and 100 nautical mile sulfur content rulings. Applies to all
 126 ocean going vessels on hoteling, maneuvering, anchorage, transit states operating on auxiliary, main, or boiler.

Reference Conventional Fuel	residual fuel oil (RFO)		Diesel (DSL)	
	Fraction remaining	Efficiency	Fraction remaining	Efficiency
CO	-	-	-	-
NOx	-	-	-	-
SOx	0.40	60%	0.07	93%
ROG	-	-	-	-
PM	-	-	-	-

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130 **Table S23: Marine biodiesel and diesel PM size distribution changes.**

Bin	Rp	DSL	B100
Index	Midpoint		
	(nm)	Mass	Mass
		Frac	Frac
1	6.3	0.0050	0.0078
2	10	0.0010	0.0054
3	16	0.0038	0.0076
4	25	0.0207	0.0354
5	39.5	0.0907	0.2499
6	63	0.2249	0.5985
7	100	0.3158	0.0806
8	160	0.2235	0.0148
9	250	0.1019	0.0000
10	395	0.0126	0.0000
11	630	0.0000	0.0000
12	1000	0.0000	0.0000
13	1600	0.0000	0.0000
14	2500	0.0000	0.0000
15	3950	0.0000	0.0000

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134 **Table S24: Population growth rate between 2050 and 2010.**

County	2050:2010 Population	County	2050:2010 Population
Alameda	1.113	Orange	1.102
Alpine	0.985	Placer	1.562
Amador	1.184	Plumas	0.983
Butte	1.515	Riverside	1.747
Calaveras	1.321	Sacramento	1.452
Colusa	1.711	San Benito	1.479
Contra Costa	1.415	San Bernardino	1.594
Del Norte	1.127	San Diego	1.279
El Dorado	1.565	San Francisco	1.126
Fresno	1.619	San Joaquin	2.009
Glenn	1.351	San Luis Obispo	1.256
Humboldt	1.099	San Mateo	1.244
Imperial	1.863	Santa Barbara	1.194
Inyo	1.244	Santa Clara	1.205
Kern	2.209	Santa Cruz	1.153
Kings	1.706	Shasta	1.46
Lake	1.636	Sierra	1.125
Lassen	1.183	Siskiyou	1.161
Los Angeles	1.164	Solano	1.435
Madera	2.138	Sonoma	1.237
Marin	1.048	Stanislaus	1.673
Mariposa	1.264	Sutter	2.241
Mendocino	1.136	Tehama	1.551
Merced	1.941	Trinity	1.325
Modoc	1.119	Tulare	1.77
Mono	1.335	Tuolumne	1.118
Monterey	1.304	Ventura	1.207
Napa	1.354	Yolo	1.476
Nevada	1.425	Yuba	1.991

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Table S25: Statewide in-state electricity generation and scenario scaling by energy resource.

	2010	GWh		2050:2010 Scaling Factor	
		2050 BAU	2050 GHG- Step	2050 BAU	2050 GHG- Step
Coal	2404	0	0	0.000	0.000
Oil	36	0	0	0.000	0.000
Gas	139314	193289	94463	1.387	0.678
Nuclear	32202	0	0	0.000	0.000
Hydro	37557	39057	63152	1.040	1.681
Biomass	3283	23532	0	7.168	0.000
Wind	6079	13956	60963	2.296	10.03
Solar	658	0	142804	0.000	217.0
Geothermal	12919	11100	11100	0.859	0.859
Total	323920	416219	643373	1.285	1.986

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140 Table S26: SWITCH load-area CA statewide in-state generation (GWh) by energy resource averaged across 15 scenarios in 2050.

	coal	oil	natural gas	nuclear	hydro	biomass	wind	solar	geo-thermal
statewide	1097	0	120700	0	29613	7383	83653	81065	38591
CA_IID	0	0	0.036	0	0.804	1.627	2.241	5.835	48.648
CA_LADWP	0	0	15.671	0	0.288	2.751	0.124	1.506	0
CA_PGE_BAY	0	0	4.614	0	0	10.079	0.511	0.553	0
CA_PGE_CEN	40.535	0	12.017	0	33.105	8.468	0.319	4.350	0
CA_PGE_N	0	0	0.683	0	52.635	23.067	25.819	23.181	42.091
CA_PGE_S	0	0	15.523	0	0.575	3.952	6.776	8.258	0
CA_SCE_CEN	59.465	0	1.037	0	4.751	22.089	55.011	46.078	9.261
CA_SCE_S	0	0	26.558	0	3.959	15.564	7.175	2.746	0
CA_SCE_SE	0	0	0.004	0	1.498	2.351	0.388	0.102	0
CA_SCE_VLY	0	0	9.489	0	0.348	2.248	0	2.385	0
CA_SDGE	0	0	2.776	0	0.141	6.110	1.636	2.014	0
CA_SMUD	0	0	11.593	0	1.897	1.696	0	2.993	0

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142 Table S27: CA-TIMES 2050:2010 scaling factor for BAU scenario for each SWITCH load area within California.

	CA_IID	CA_LADWP	CA_PGE_BAY	CA_PGE_CEN	CA_PGE_N	CA_PGE_S	CA_SCE_CEN	CA_SCE_S	CA_SCE_SE	CA_SCE_VLY	CA_SDGE	CA_SMUD
coal	1	1	0	0	1	0	0	1	1	0	1	1
oil	1	1	1	1	1	1	1	1	1	1	1	1
natural gas	0.458	3.641	0.533	1.495	0.346	1.339	0.173	1.254	0.005	4.395	0.664	3.787
nuclear	1	1	1	1	1	0	1	1	1	1	1	1
hydro	1.021	1.056	1.000	1.044	1.033	1.079	1.060	1.061	1.024	1.099	1.027	1.070
biomass	9.996	11.06	10.29	4.078	5.044	9.996	10.03	9.860	9.996	2.828	11.33	10.27
wind	312.6	0.319	0.061	1.727	3.549	12.04	2.691	1.283	54.20	1.000	2.271	1.000
solar	95	0	1	0	1	0	0	1	0	0	0	1
geo-thermal	0.798	1	1	1	3.422	1	0.215	1	1	1	1	1

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144 Table S28: CA-TIMES 2050:2010 scaling factor for GHG-Step scenario for each SWITCH load area within California.

	CA_IID	CA_LADWP	CA_PGE_BAY	CA_PGE_CEN	CA_PGE_N	CA_PGE_S	CA_SCE_CEN	CA_SCE_S	CA_SCE_SE	CA_SCE_VLY	CA_SDGE	CA_SMUD
coal	1	1	0	0	1	0	0	1	1	0	1	1
oil	1	1	1	1	1	1	1	1	1	1	1	1
natural gas	0.224	1.780	0.260	0.731	0.169	0.654	0.084	0.613	0.003	2.148	0.32	1.851
nuclear	1	1	1	1	1	0	1	1	1	1	1	1

hydro	1.651	1.707	1.000	1.688	1.670	1.745	1.714	1.716	1.655	1.777	1.66 1	1.730
biomass	0	0	0	0	0	0	0	0	0	0	0	0
wind	1365.9 00	1.392	0.266	7.545	15.501	52.61 6	11.75 6	5.602	236.7 76	1.000	9.92 0	1.000
solar	383.36 9	51.95 5	789.2 36	362.4 77	33103.3 16	184.1 13	150.8 42	3921.2 51	63.47 8	91.42 4	75.7 04	4274.5 63
geothermal	0.798	1	1	1	3.422	1	0.215	1	1	1	1	1

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Table S29: The fraction of electricity generation imports for each fuel category

	2010	2050 BAU	2050 GHG-Step
Coal	0.939	0.939	0.939
Oil	0.448	0.448	0.448
Gas	0.168	0.168	0.168
Nuclear	0.196	0.000	0.000
Hydro	0.302	0.000	0.000
Biomass	0.000	0.000	0.000
Wind	0.000	0.826	0.725
Solar	0.000	1.000	0.342
Geothermal	0.000	0.608	0.608

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149 Table S30: List of CA-TIMES biofuel variables and descriptions used in biofuel production.

Category	Variable	Acronym Description
feedstock	SUPELC	Electricity (SUP)
feedstock	SUPBIOFOR	Biomass, Forest residues (SUP)
feedstock	SUPBIOMSWM	Biomass, Municipal solid waste (mixed) (SUP)
feedstock	SUPBIOMSWP	Biomass, Municipal solid waste (paper) (SUP)
feedstock	SUPBIOMSWW	Biomass, Municipal solid waste (wood) (SUP)
feedstock	SUPBIOMSWY	Biomass, Municipal solid waste (yard) (SUP)
feedstock	SUPBIOOVW	Biomass, Orchard and vineyard waste (SUP)
feedstock	SUPBIO PULP	Biomass, Pulpwood (SUP)
feedstock	SUPBIOAGR	Biomass, Agricultural residues (stovers and straws) (SUP)
feedstock	SUPBIOENC	Biomass, Energy crops (SUP)
feedstock	SUPBIOYGR	Biomass, Yellow grease (SUP)
feedstock	SUPBIOTAL	Biomass, Tallow (SUP)
feedstock	SUPGSL	Pure Gasoline (SUP)
\I: Biodiesel Production	PYGRDSL100	Biodiesel Production - Biodiesel from yellow grease, produced in California, 100 MGY Plant
\I: Biodiesel Production	PTALDSL100	Biodiesel Production - Biodiesel from tallow, produced in California, 100 MGY Plant
\I: Cellulosic Ethanol Production, Biochemical	PCELETHWOO100	Cellulosic Ethanol Production, Biochemical - Woody, 100 MGY Plant
\I: Cellulosic Ethanol Production, Biochemical	PCELETHMSW100	Cellulosic Ethanol Production, Biochemical - MSW, 100 MGY Plant
\I: Cellulosic Ethanol Production, Biochemical	PCELETHHRB50	Cellulosic Ethanol Production, Biochemical - Herbaceous, 50 MGY Plant
\I: Cellulosic Ethanol Production, Biochemical	PCELETHHRB100	Cellulosic Ethanol Production, Biochemical - Herbaceous, 100 MGY Plant
\I: Bio-oil Production	PPYRWOO100	Pyrolysis Bio-oil Production -Woody, 100 MGY Plant
\I: Bio-oil Production	PPYRMSW100	Pyrolysis Bio-oil Production - MSW, 100 MGY Plant
\I: Bio-oil Production	PPYRHRB100	Pyrolysis Bio-oil Production - Herbaceous, 100 MGY Plant
\I: FT Liquids Production, Polygeneration Plant (Gasoline, Diesel, and Electricity) from Coal and/or Biomass	PFTBTLWOO	FT Liquids Production, Polygeneration Plant (Gasoline, Diesel or Jet, and Electricity) from Coal and/or Biomass -Woody, 61 MGY Plant
\I: FT Liquids Production, Polygeneration Plant (Gasoline, Diesel, and Electricity) from Coal and/or Biomass	PFTBTLMSW	FT Liquids Production, Polygeneration Plant (Gasoline, Diesel or Jet, and Electricity) from Coal and/or Biomass - MSW, 61 MGY Plant

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Table S31: CA-TIMES biomass feedstocks, conversion processes, and biofuel.

Feedstock category CA-TIMES biomass feedstocks, conversion processes, and biofuel	Feedstock classes and feedstocks	Conversion Process Selected by CA-TIMES				
		Mill to EtOH	Ligno-cellulosic to EtOH	Pyrolysis to oil	fischer tropsh biomass to liquid (FTBTL) diesel	FAME/FAHC aka biodiesel
clean lingo-cellulosics	WOO: woody/pulp <ul style="list-style-type: none"> • Ag residue – straw+ stover • Orchard/vineyard waste • Pulpwood 		X	X	X	
Lingo-cellulosics	MSW: municipal solid waste <ul style="list-style-type: none"> • Wood waste • mixed_paper, • construction/demolition, • yard_waste • food waste • dirty 			X	X	
	HRB – herbaceous energy crop		X		X	
lipids	YGR/TAL <ul style="list-style-type: none"> • Yellow grease/used cooking oil • Tallow/Animal fats/lard 					X
grains	CRN – corn	X				

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Table S32: CA-TIMES biomass power plants in 2010 versus 2050. IGCC is integrated gasification combined-cycle.

Feedstock	Process	2010	2050 BAU	2050 GHG- Step
Wood/ forest residue	conventional	1035.131	0	0
Municipal solid waste (MSW)	conventional	229.2206	0	0
Herbaceous	conventional	0	0	0
Wood/ forest residue	IGCC	0	6053.336	0
Municipal solid waste (MSW)	IGCC	0	3930.507	0
Herbaceous	IGCC	0	13542.68	0

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Table S33: Emission rate scaling factor of 2020 biomass IGCC turbine versus 2010 biomass steam turbine versus steam boiler woody biomass plant emission rate factor from GREET1.8b (California Air Resources Board 2009).

	CA 2010 Biomass power plant average (g kWh ⁻¹)	Assumed Biomass IGCC emission factor (g kWh ⁻¹)	Bio IGCC scaling factor
CO	0.027	0.003	0.103
NOx	0.626	0.042	0.067
SOx	1.070	0.998	0.932
ROG	0.225	0.040	0.178
PM	0.225	0.074	0.331
NH3	0.126	0.011	0.085

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163 **Table S34: California estimate of maximum biofuels available (million gallons per year) based on biomass feedstock**
164 **supply curves.**

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	CA	WGA Western US	CA fraction of WGA Western US
Total Cellulosic Ethanol	1,306	8,127	0.161
Forest	385	1,855	0.208
MSW (paper)	266	600	0.443
MSW (wood)	126	284	0.443
MSW (yard)	264	596	0.443
Orchard/Vine	192	240	0.801
Stover	45	66	0.684
Straws	28	656	0.043
Energy Crops	0	3,830	0.000
Total F-T Diesel	421	952	0.443
MSW (mixed)	421	952	0.443
Total Biodiesel	35	1,291	0.027
Yellow Grease	21	49	0.421
Animal Fats	14	236	0.061
Seed Oils (soy/canola)	0	1,005	0.000
Corn Ethanol	313	9,940	0.031

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167 **Table S35: Assumed biomass feedstock production (PJ) in California based on maximum biomass supply curves. WGA**
168 **western US is the region used in CA-TIMES. California was estimated separately to determine in-state biomass**
169 **production and hence in-state portion of biofuel supply.**

	2010 WGA Western US	2050 WGA Western US	2050 CA
Biomass Feedstocks Total	39.8	1,662.0	
Forest Residues	3.4	109.4	22.7
MSW - Mixed (Dirty + Food)	18.1	329.7	146.0
MSW - Paper	0.0	106.6	47.2
MSW - Wood	0.0	75.2	33.3
MSW - Yard	0.0	28.9	12.8
Orchard & Vineyard Waste	17.2	95.5	76.5
Pulpwood	0.0	30.0	30.0
Agricultural Residues (Stovers + Straws)	0.4	246.2	25.1
Herbaceous Energy Crops	0.0	394.3	0.0
Yellow Grease	0.0	144.8	61.0
Tallow	0.8	101.3	6.2
Corn	0.0	0.0	0.0
Digester Gas and Landfill Gas	28.0	9.6	9.6
Miscellaneous Biomass	30.1	48.2	48.2

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172 **Table S36: Particulate matter size and species (except metals) emission rate contribution percent change for**
173 **each emission source category in the GHG-Step scenario relative to the BAU scenario.**

Source Category	PM _{0.1}	PM _{2.5}	EC	OC	SO ₄ ²⁻	NO ₃ ⁻	OTHER
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Vehicle Brake & Tire Wear	-0.1%	-4.2%	-9.4%	-6.7%	0.0%	0.0%	0.0%
Vehicle Exhaust & Evaporative	-2.4%	-1.0%	-1.4%	-1.6%	-0.2%	-0.4%	-0.2%
Rail & Other Off-road	-0.3%	+0.4%	-12.7%	+4.8%	-0.1%	-4.7%	0.0%
Marine & Aviation	-2.4%	+8.0%	+14.5%	+3.4%	+21.8%	+15.6%	+5.3%
Residential & Commercial	-14.2%	-2.0%	0.0%	-5.5%	-2.9%	-5.1%	0.0%
Electricity	-15.7%	-4.4%	-1.5%	-6.5%	-13.5%	-5.6%	-1.4%
Industrial & Agricultural	-0.9%	-0.4%	0.0%	-1.2%	-1.3%	-1.2%	-1.0%
Miscellaneous	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Net Total	-35.9%	-3.6%	-10.6%	-13.3%	3.7%	-1.3%	+2.6%

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175 **Table S37: Metal particulate matter emission rate contribution percent change for each emission source**
176 **category in the GHG-Step scenario relative to the BAU scenario.**

Source Category	METL	CU	MN	FE
Vehicle Brake & Tire Wear	-3.4%	-61.9%	-17.2%	-23.4%
Vehicle Exhaust & Evaporative	-0.1%	0.0%	0.0%	0.0%
Rail & Other Off-road	-0.1%	0.0%	0.0%	0.0%
Marine & Aviation	+0.4%	0.0%	0.0%	0.0%
Residential & Commercial	-0.1%	0.0%	0.0%	0.0%
Electricity	-0.7%	-0.5%	-2.3%	-0.2%
Industrial & Agricultural	-0.6%	-0.1%	-0.3%	-0.2%
Miscellaneous	0.0%	0.0%	0.0%	0.0%
Net Total	-4.5%	-62.5%	-19.9%	-23.8%

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178 **Table S38: Emission rate contribution percent change for gaseous species in each source category in the GHG-**
179 **Step scenario relative to the BAU scenario.**

Source Category	CO	NO_x	SO_x	NH₃
Vehicle Brake & Tire Wear	0.0%	0.0%	0.0%	0.0%
Vehicle Exhaust & Evaporative	-21.9%	-3.5%	-1.7%	-1.3%
Rail & Other Off-road	+64.2%	-12.7%	+0.1%	0.0%
Marine & Aviation	+1.3%	+8.3%	+24.1%	0.0%
Residential & Commercial	-1.0%	-1.9%	+0.1%	-0.1%
Electricity	-4.8%	-2.6%	-7.1%	-3.2%
Industrial & Agricultural	-0.6%	-1.3%	-1.8%	-22.9%
Miscellaneous	0.0%	0.0%	0.0%	0.0%
Net Total	+37.3%	-13.7%	+13.6%	-27.5%

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