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QUANTIFYING THE COMPREHENSIVE GREENHOUSE GAS CO-BENEFITS OF GREEN BUILDINGS

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Project Purpose

- Estimate GHG emissions due to:
    - Water use
    - Solid waste disposal
    - Transportation

in certified green commercial buildings in CA

Project Need

- Green buildings a major GHG-fighting strategy at state and municipal levels
- Heavy focus on energy efficiency in buildings
- No full accounting of GHG co-benefits of water, solid waste, and transportation measures

Project Goals

- Achieve more complete assessment of potential GHG benefits of green buildings
- Facilitate progress toward GHG goals by allowing fuller accounting of green building benefits
- Stimulate voluntary actions to reduce emissions by documenting role of green buildings
- Inform future building standards-setting

Key Findings

- Green office buildings, compared to conventional construction, produce:
  - 50% less GHGs due to water consumption;
  - 48% less GHGs due to solid waste;
  - 5% less GHGs due to transportation

- If entire CA office building stock achieved performance typical of the green buildings, state could save about 0.831 MMT CO2e/yr

Analytical Comparisons

Table 1. Definitions of baseline, measured and predicted values

	Definition	*Major data sources*		
		Water	*Waste*	*Transportation*
Baseline value	Performance of typical, non-green office buildings in California	Gleick et el (2003)	CalRecycle (2006)	2008-2012 American Community Survey
Predicted value	Performance expected of green office building at the time of certification	California Green Building Standards Code, 2010 edition (CalGreen)	AB 341	CAPCOA (2010)
Measured value	Actual performance of green office buildings	Performance data from certified LEED-EBOM office buildings	Performance data from certified LEED-EBOM office buildings	Performance data from certified LEED-EBOM office buildings

Green Building Data Source

- LEED-EBOM is primary data source
  - Strength: Provides operational data
  - Weakness: Little information on strategies
- Focus on commercial OFFICE buildings only
- Included buildings certified under LEED-EBOM 2008 and 2009

LEED-EBOM notes

- LEED is a menu, not a recipe
- Many get credit just for measuring usage of water, waste, and transportation
- Additional credits available for achieving specified performance levels
- Minimal information on strategies used to achieve these performance levels

LEED-EBOM credits

- WEpre – Either 120% or 160% of 2006 IPC
- WEc1.1 – Report whole building water use
- WEc1.2 – Report on any submetered usage
- WEc2 – Up to 30% reduction in indoor water use

- MRpre – Have solid waste management plan
- MRc6 – Report on waste audit
- MRc7 – Divert at least 50% of consumables

- SSc4 – Reduce AVR by up to 75%

Key Performance Data

- Water: Total usage (WEc1.1), partial submetering (WEc1.2), indoor efficiency credit (WEc2)
- Waste: Diversion percentage (converted from MRc6), diversion percentage toward 50% goal (MRc7)
- Transportation: Average vehicle ridership (SSc4)

Regional Variations

- Regional variations in:
  - Irrigation demand
  - Energy intensity of water
  - Regional transportation infrastructure

- Performed all calculations for:
  - Bay Area
  - Los Angeles
  - San Diego
  - Sacramento
  - Rest of California

Size of Database

Table 2. Qualifying LEED-EBOM buildings with data in each resource area, by region

	Transportation	**Water**	**Waste**
SF Bay Area	99	89	105
LA metro	54	63	74
Sacramento metro	21	22	31
San Diego metro	16	11	14
Rest of CA	6	6	9
Total	**196**	**191**	**233**

Baseline Water Use

Table 3. Water baselines considered for use in analysis
(gallons/sf/yr)

	Dziegielewski (AWWA survey)	Gleick 1 (Pacific Inst from MWD survey)	Gleick 2 (Pacific Inst modeled)
Indoor	73.0	74.4	42.1
Irrigation	365.2	72.5	31.1
Cooling	66.1	43.9	34.9
Total	**504.3**	**190.8**	**108.1**

Sources: Derived from Dziegielewski (2000), Gleick et al (2003)

Predicted Water Use

Table 4. Predicted indoor water use from 2010 CalGreen and CA Plumbing Codes

(Relevant fixtures and characteristics only)

Fixture	Flow rate			Duration		Daily uses			Fixture water use	Occupant load	Fixture water use	
	gal/min	gal/cycle	gal/flush	min	flush	all	male	female	gal/occupant/workday	(sf/occupant)	gal/tsf/workday	gal/sf/yr
Lavatory faucets	0.5			0.25		3			0.4	200	1.88	0.5
Kitchen faucets	2.2			4		1			8.8	200	44.00	11.4
Metering faucets		0.25		0.25		3			0.2	200	0.94	0.2
Water closets			1.6		1		1	3	6.4	200	32.00	8.3
Urinals			1		1		2		2.0	200	10.00	2.6
Total indoor											88.81	23.1

Table 5. Predicted irrigation usage from CalGreen code

	Sac metro (Sacramento)	Bay Area (Oakland)	LA metro (LA)	SD metro (SD)	Rest of CA (Redding)
Evapotranspiration rate (in/yr)	51.9	41.8	50.1	46.5	48.8
Estimated Total Water Use (gal/irrigated sf/yr)*	27.2	21.9	26.2	24.4	25.6
Estimated Total Water Use (gal/building sf/yr)**	9.2	7.4	8.9	8.3	8.7

Sources: 2010 California Green Building Standards Code, Section 5.304.1

DWR, 2010, Water Budget Workbook, Beta Version 1.01

Measured Water Use

1. Calculate the average total building usage for all buildings not excluded for reporting errors

2. Calculate the average irrigation usage (for buildings sub-metering irrigation usage) and the average cooling tower usage (for buildings sub-metering cooling tower usage)

3. Impute the average indoor usage by subtracting the irrigation average and the cooling tower average from the whole-building average

4. Break these results down by region.

GHG Intensity of Water

Table 6. Energy and GHG intensities for regional marginal water supplies

Region	Assumed origin	Quantity	Energy intensity of water		GHG intens. of energy	GHG intensity of water	
			Outdoor	Indoor		Outdoor	Indoor
		(TAF)	(kWh/MG)	(kWh/MG)	(MT/kWh)	(MT/gal)	(MT/gal)
Bay Area	State Water Project	188	2,817	9,869	0.000270	0.000000761	0.00000266
	Hetch Hetchy	265	1,383	8,435	0.000270	0.000000373	0.00000228
	Mokelumne	365	1,543	8,595	0.000270	0.000000417	0.00000232
	Weighted average		1,784	8,835	0.000270	0.000000482	0.00000239
Sac metro	Local/intrabasin		1,503	8,555	0.000233	0.000000350	0.00000199
SD metro	State Water Project (East)		3,459	10,511	0.000270	0.000000934	0.00000284
LA metro	State Water Project (East)		3,459	10,511	0.000270	0.000000934	0.00000284
Rest of state	Groundwater		2,279	9,331	0.000270	0.000000615	0.00000252

Source for water energy intensities: CAPCOA (2010), Table WSW-3.1, p. 345; Blanco et al (2012) for State Water Project

Source for marginal GHG intensities of energy: ARB personal communication; Sacramento marginal intensity from E3 (2010)

Source for Hetch Hetchy and Mokelumne diversion quantity: http://www.aquafornia.com

Source for water heating energy intensity incorporated in indoor estimate: NRDC (2004)

Baseline Solid Waste

- Waste generated by large office buildings:
  1,998 pounds per 1000 square feet

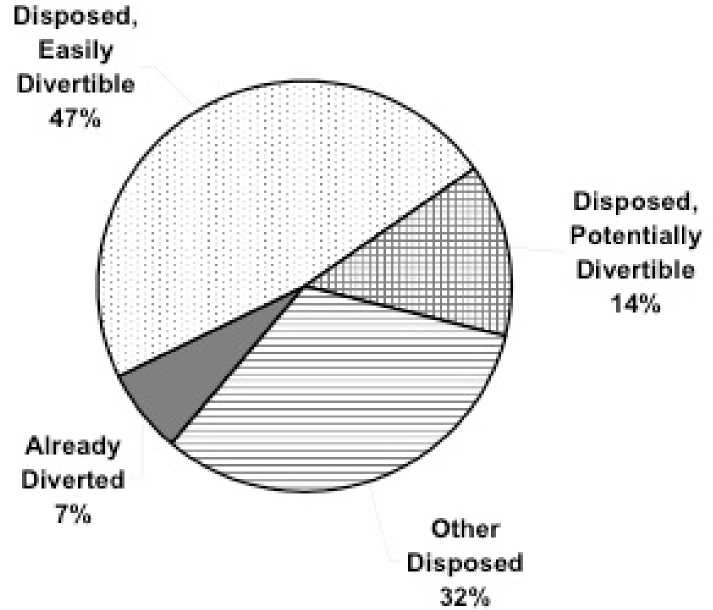


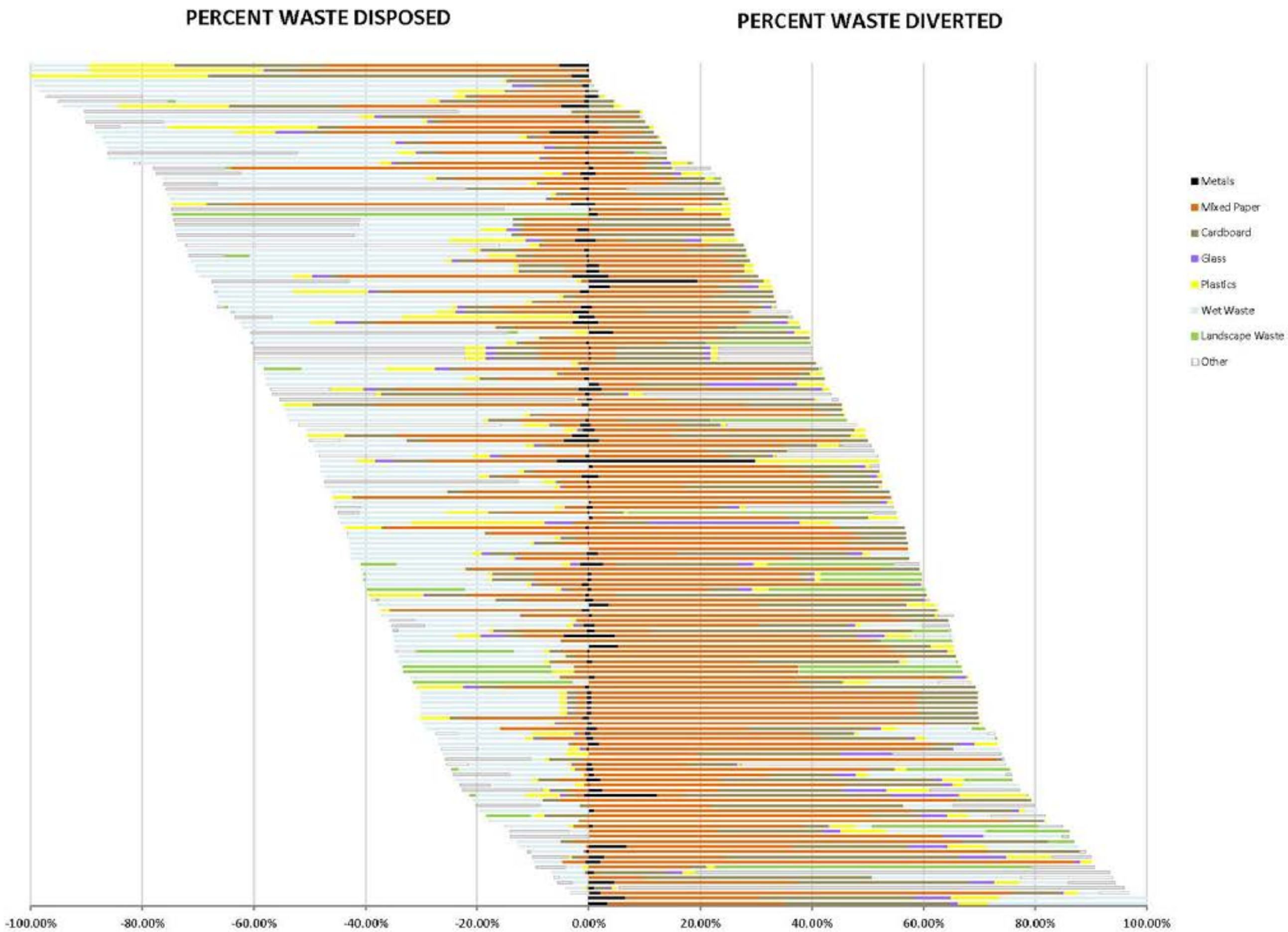
Figure 1. Diverted and divertible waste material in CA large office buildings, 2005 (CalRecycle 2006).

Predicted Solid Waste

- AB 341 requires 50% diversion rate for jurisdictions
- At the time of building certification, this represented the state’s aspirational goal for green building

Measured Solid Waste

'igure 9. Percentage of waste disposed and diverted for each LEED-certified building in the study dataset, by materi



GHG Intensity of Solid Waste

- Adapted formulas from Landfill Emissions Tool v1.3
- Assume:
  - 70% of landfilled waste is wet waste
  - 30% of landfilled waste is paper
  - Landfills have gas collection systems
- Methane emissions converted to CO2e

Baseline Transportation

- Developed new method for calculating baseline regional AVR
- American Community Survey data, 2008-2012
- Regional baseline AVR =

$$\frac{Number\ of\ commuters}{Number\ of\ vehicles} = \frac{N_{total}}{(V_{DA} + V_{CP})}$$

N_{total} = total number of commuters
V_{DA} = total # of vehicles used to drive alone
V_{CP} = total # of vehicles used for carpooling

Baseline Transportation

Table 9. Baseline average vehicle ridership (AVR) for major CA regions

	Commuters	Vehicles	AVR
Bay Area	3,400,199	2,444,789	1.39
LA metro	7,886,161	6,271,379	1.26
Sacramento metro	984,449	792,260	1.24
SD metro	1,431,134	1,152,142	1.24
Rest of state	11,810,893	9,116,305	1.29

Predicted Transportation

- Adjusted the baseline using CAPCOA formula:

Figure 2. Equations for calculating transit mode share as a function of distance of destination to transit.

Distance to transit	Transit mode share calculation equation (where x = distance of project to transit)
0 – 0.5 miles	-50*x + 38
0.5 to 3 miles	-4.4*x + 15.2
> 3 miles	no impact

- Add transit (rail) trips to regional AVR, reduce drive alone and carpooling proportionally

Measured Transportation

Table 12. Assumed measured AVRs for each LEED-EBOM point bin's lower threshold

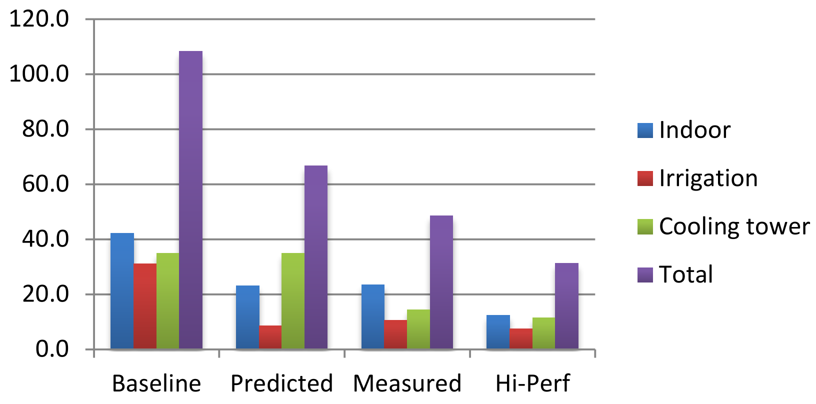
Demonstrated % reduction in conventional commuting trips	Assumed measured AVR
10	1.125
13.75	1.171875
17.50	1.21875
21.25	1.265625
25	1.3125
31.25	1.390625
37.5	1.46875
43.75	1.546875
50	1.625
56.25	1.703125
62.50	1.78125
68.75	1.859375
75	1.9375

GHG Intensity of Transp.

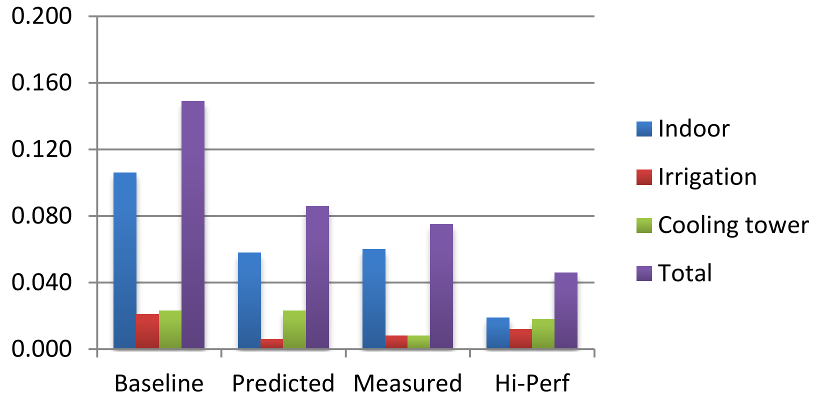
- Weighted average of GHG intensities of each mode, proportional to regional usage rate
- Assumed same building occupancy rate as plumbing code (5 occupants per 1000sf)
- Assumed average commute distance of 24 miles/person/day

Water Results

All buildings, by usage type



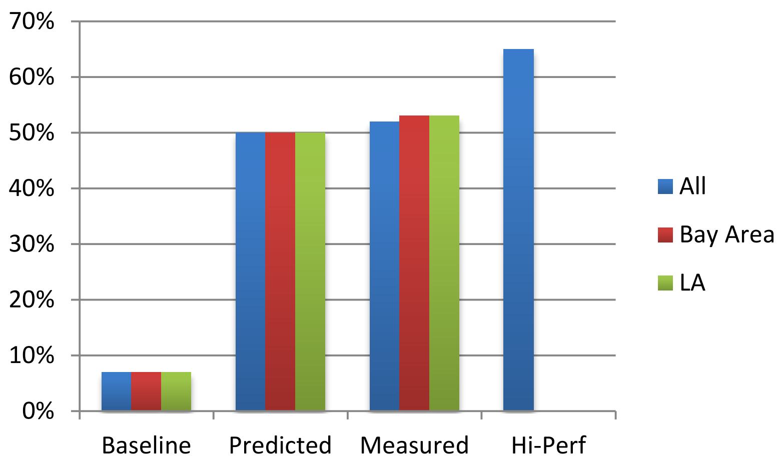
Water usage (gal/sf/yr)



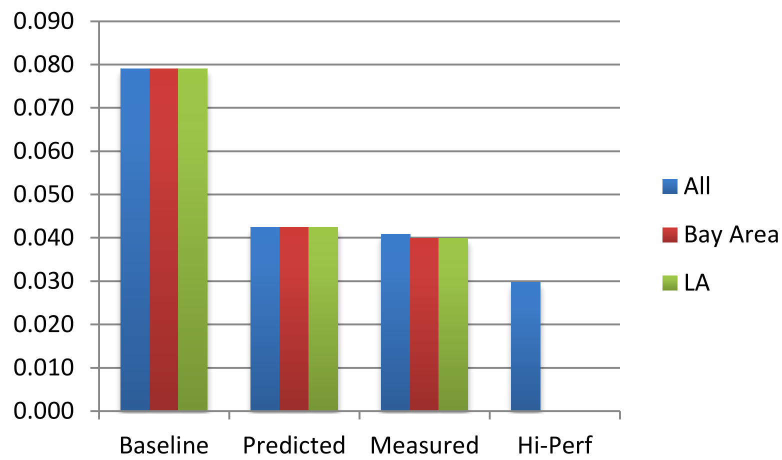
GHG emissions (MT CO_2e/1000sf/yr)

Waste Results

All buildings, with Bay Area and LA



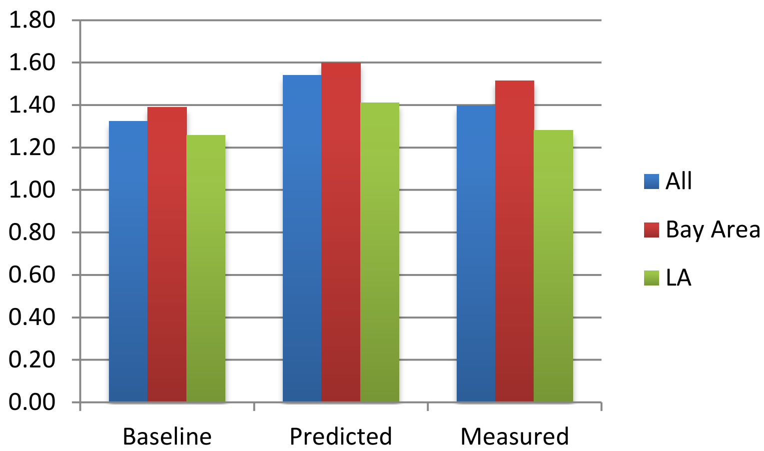
Diversion rate (%)



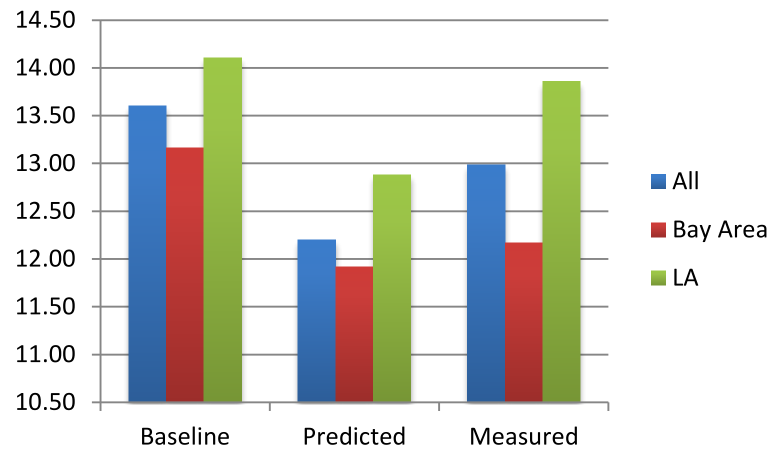
GHG emissions (MT CO_2e/1000sf/yr)

Transportation Results

All buildings, with Bay Area and LA



AVR



GHG emissions (MT CO_2e/1000sf/yr)

Summary of Results

Table 18. Summary of GHG Emissions Rates from Water, Waste and Transportation in CA Certified Green Office Buildings

	N	Baseline	Predicted	Measured	Hi-Performance	GHG Improvements		
		GHG emissions MT CO2e/1000sf/yr	GHG emissions MT CO2e/1000sf/yr	GHG emissions MT CO2e/1000sf/yr	GHG emissions MT CO2e/1000sf/yr	Base-Measure	Pred-Measure	Base-Hi Perf
Water	191	0.149	0.086	0.075	0.046	50%	13%	69%
Waste	233	0.079	0.043	0.041	0.030	48%	4%	62%
Transportation	196	13.605	12.204	12.988		5%	-6%	
Operational energy (for comparison)		5.289						

Summary of Results

Table 19. Summary of GHG Emissions Co-Benefits from Water, Waste and Transportation in CA Office Buildings

All figures in MT CO2e/yr

	Baseline Emissions	Predicted Emissions	Measured Emissions	Hi-Performance Emissions	Potential GHG Improvements		
					Base-Measure	Pred-Measure	Base-Hi Perf
Average office building (12,968 sf)							
Water	1.93	1.12	0.97	0.60	0.96	0.14	1.34
Waste	1.03	0.55	0.53	0.39	0.50	0.02	0.64
Transportation	176.42	158.26	168.43		8.00	(10.17)	
All CA office buildings (1.14 billion sf)							
Water	169,860.00	98,040.00	85,500.00	52,440.00	84,360.00	12,540.00	117,420.00
Waste	90,117.00	48,450.00	46,512.00	33,915.00	43,605.00	1,938.00	56,202.00
Transportation	15,509,159.25	13,912,303.64	14,806,132.50		703,026.75	(893,828.86)	
Total	**15,769,136.25**	**14,058,793.64**	**14,938,144.50**	**14,892,487.50**	**830,991.75**	**(879,350.86)**	**876,648.75**

Major Conclusions

- Transportation GHGs dwarf water and waste
- Water and waste performance significantly better for certified green buildings (~50% usage drop)
- Extra performance incentives prompt even greater efficiency improvements than EBOM rewards
- Performance and prediction diverge for irrigation usage and transportation

Transportation Issues

- Prediction method is conservative, yet buildings still fall short of it
- Buildings certified in other LEED systems may perform better on transportation
- Trends in commute distances are very important to shaping transportation GHGs – this method doesn't incorporate this issue

Discussion Points

- LEED-EBOM buildings are existing buildings, so these findings have most pertinence to retrofits
- New construction should be able to do better
- CalGreen has taken effect now, has prescriptive but not yet any mandatory performance thresholds for water, waste or transportation

Discussion Points

- ARB goal to achieve 7.5 MMT CO2e/yr emission reduction from green commercial buildings (not just office)

- These findings are not directly comparable to this goal, but are plausibly consistent with it

- GHG intensity of water (and operational energy) will drop over time as electricity system gets cleaner

Recommendations

- Address transportation emissions through CalGreen or other building codes if possible
- Improve baseline and prediction calculation methods, especially for transportation
- CalGreen should strengthen plumbing standards and require composting

Recommendations

- Encourage all buildings to make performance data public (not just green buildings)
- Include questions on water, waste and transportation in CEUS and CBECS
- Expand emphasis on existing buildings in climate planning efforts

Questions?

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