Contribution of Medium-Sized Commercial Buildings

by

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Outline

- Study Overview
- DER-CAM Overview, the **D**istributed **E**nergy **R**esources **C**ustomer **A**doption **M**odel
- CEUS Database
- Results for Medium-Sized Commercial Buildings
- PRAC Update
- “Appendix”: More CEUS / Result Background

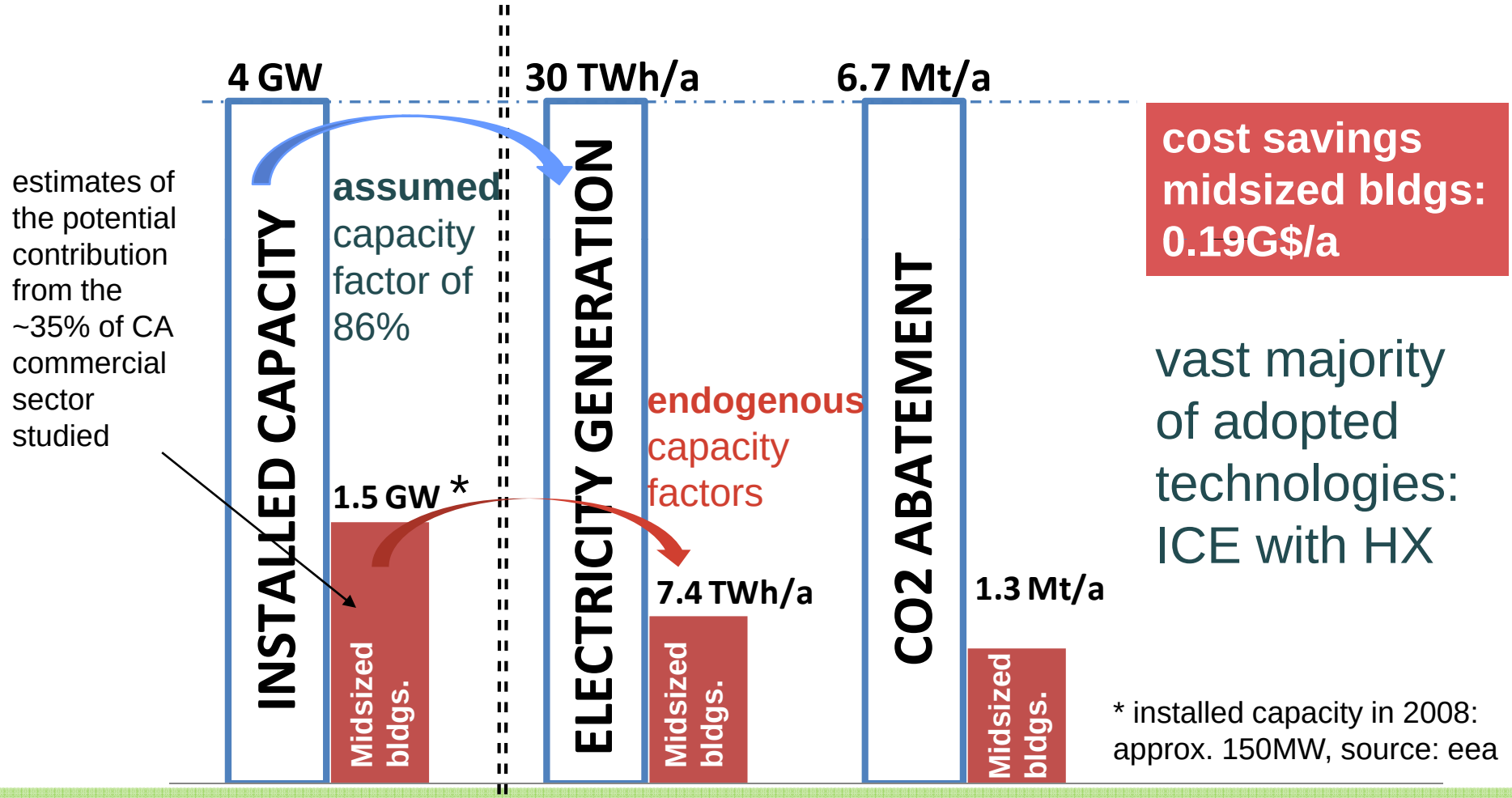
Study Overview: CHP in CA Medium-Sized Commercial Buildings

Study Summary

- objective: to estimate the 2020 CO_2 abatement potential of CHP for medium-sized CA commercial buildings (100 kW – 5 MW electric peak load)
- pick a sample of representative buildings from CEUS
- use DER-CAM to examine CHP attractiveness in sample, with competition from other technologies, e.g. PV
- estimate and report CO_2 results relative to CARB goals
- model reference case and alternative scenarios including carbon taxes and “feed-in tariff” (FiT) cases in relation to AB 32 and AB 1613
- propose further work in this under-explored sector

Results Summary
(Reference Case)

Incremental 4 GW CHP CARB 2020 GOAL



estimates of the potential contribution from the ~35% of CA commercial sector studied

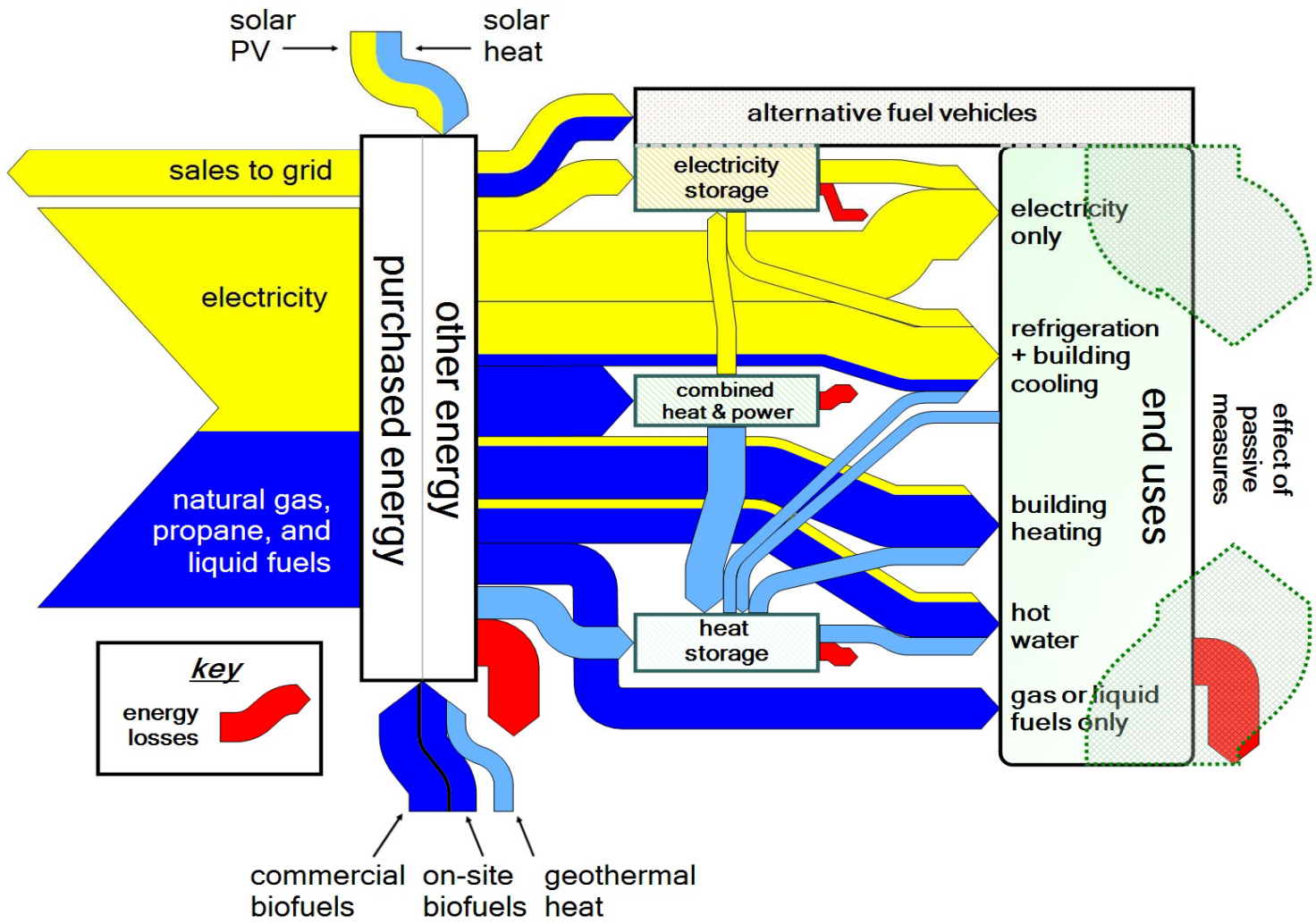
cost savings midsized bldgs: 0.19G$/a

vast majority of adopted technologies: ICE with HX

* installed capacity in 2008: approx. 150MW, source: eea

Distributed Energy Resources Customer Adoption Model (DER-CAM)

DER-CAM Concept



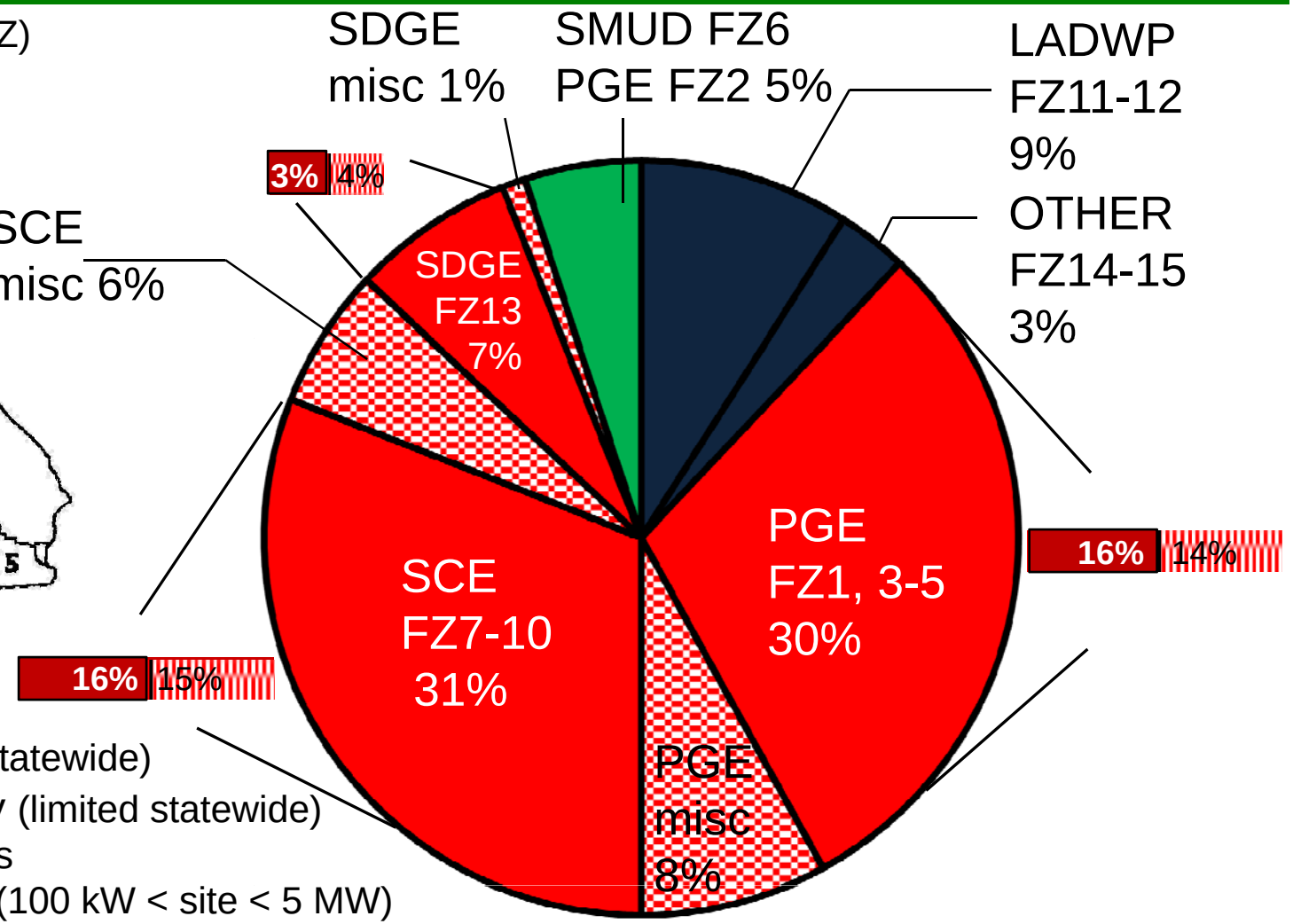
Key Features DER-CAM

- considers multiple technologies as CHP, PV, solar thermal, and storage at the same time
- optimizes costs and / or CO_2 emissions
- uses a bottom up approach, every single building is considered in detail
- can also analyze zero-net energy buildings by adding that as a constraint

CEUS Database

35% of Commercial Electric Demand

Forecasting zones (FZ)



California (statewide)

CEUS study (limited statewide)

excluded sites

studied sites (100 kW < site < 5 MW)

Building Data Sample

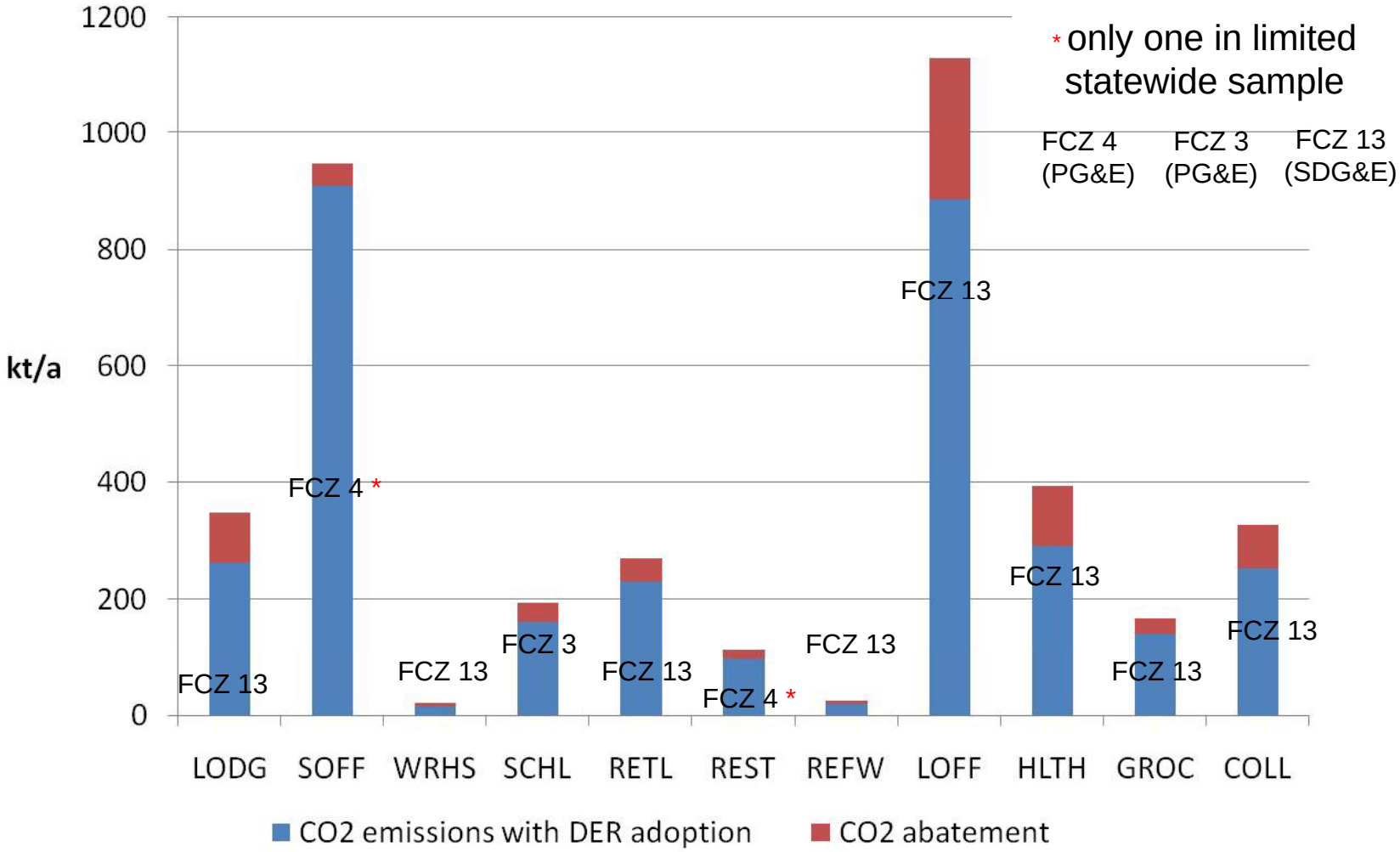
- Objective: to estimate the 2020 CO_2 abatement potential of CHP for medium-sized CA commercial buildings (100 kW – 5 MW electric peak load)
- Scope: buildings with electricity peak within range of 100 kW – 5 MW (35% of total electric demand)
- Building sample: 138 buildings of different types and in various climate zones

Results for Medium-Sized Commercial Buildings

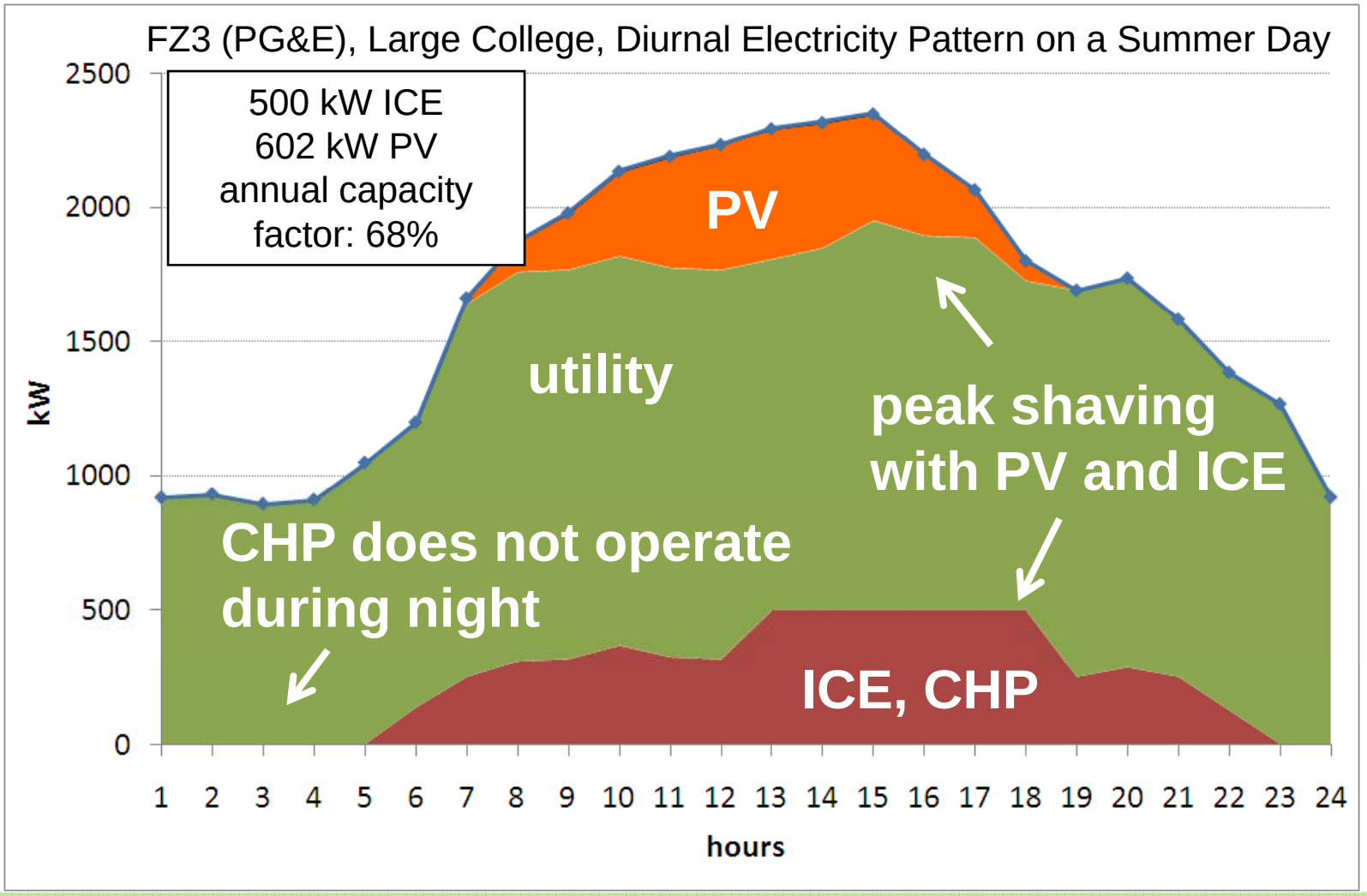
Key Assumptions

- not only CHP is considered, also PV, solar thermal
- technology costs in 2020 are based on “Assumptions to the Annual Energy Outlook”, e.g.
  - FC with HX: $2220 - $2770/kW, lifetime: 10 years
  - ICE with HX: $2180 - $3580/kW, lifetime: 20 years
  - PV: $3237/kW, lifetime: 20 years
  - etc.
- natural gas tariffs are constant in real terms
- electricity tariffs from early 2009 / late 2008 are used and constant in real terms
- 6% real interest rate (except one sensitivity run)

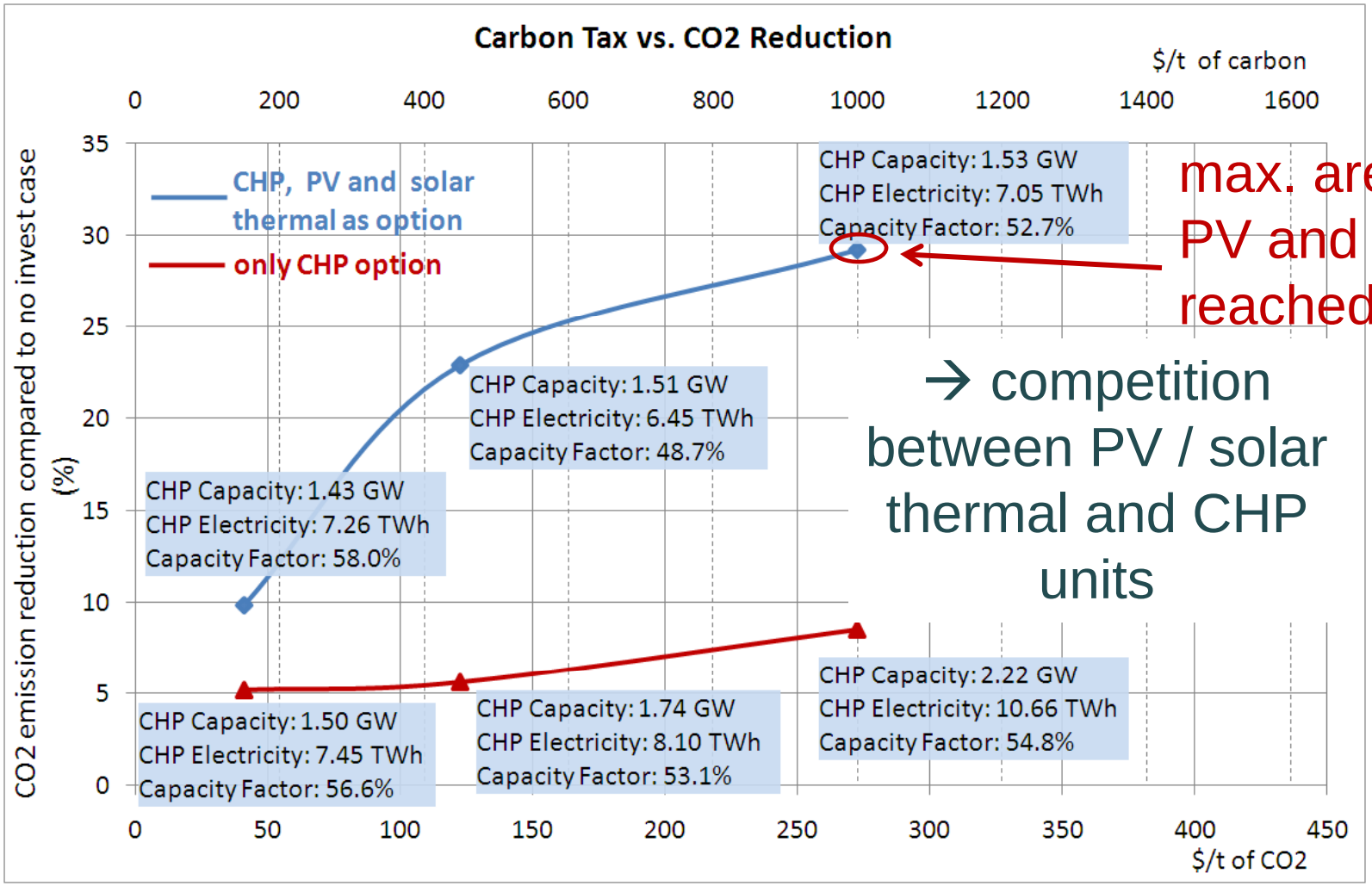
CO_2 Abatement Best Bldgs.
(Reference Case)



Electric Supply Results
(Reference Case)



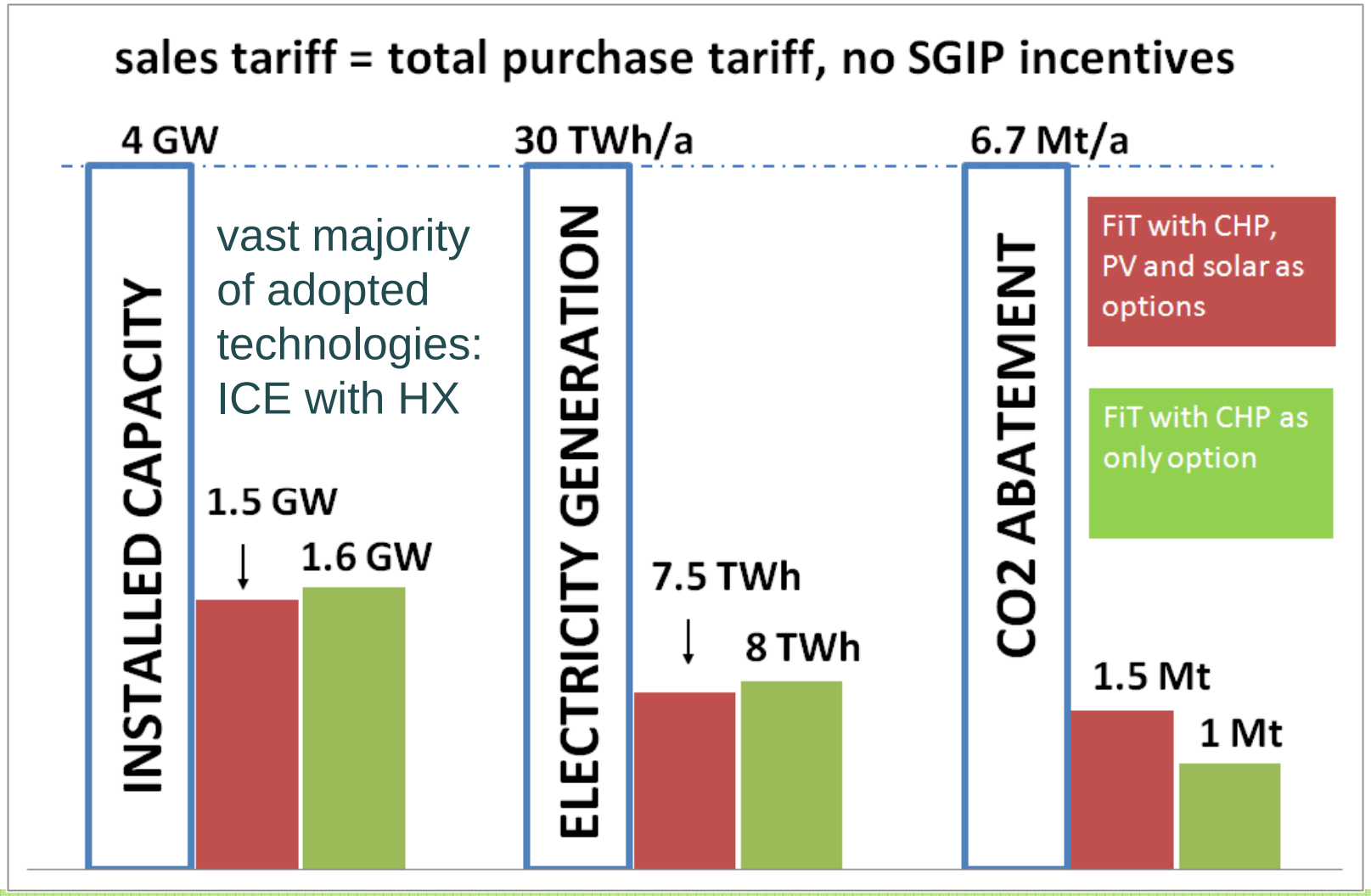
Carbon Tax Cases
(for Considered Midsized Bldgs.)



max. area for PV and solar reached?

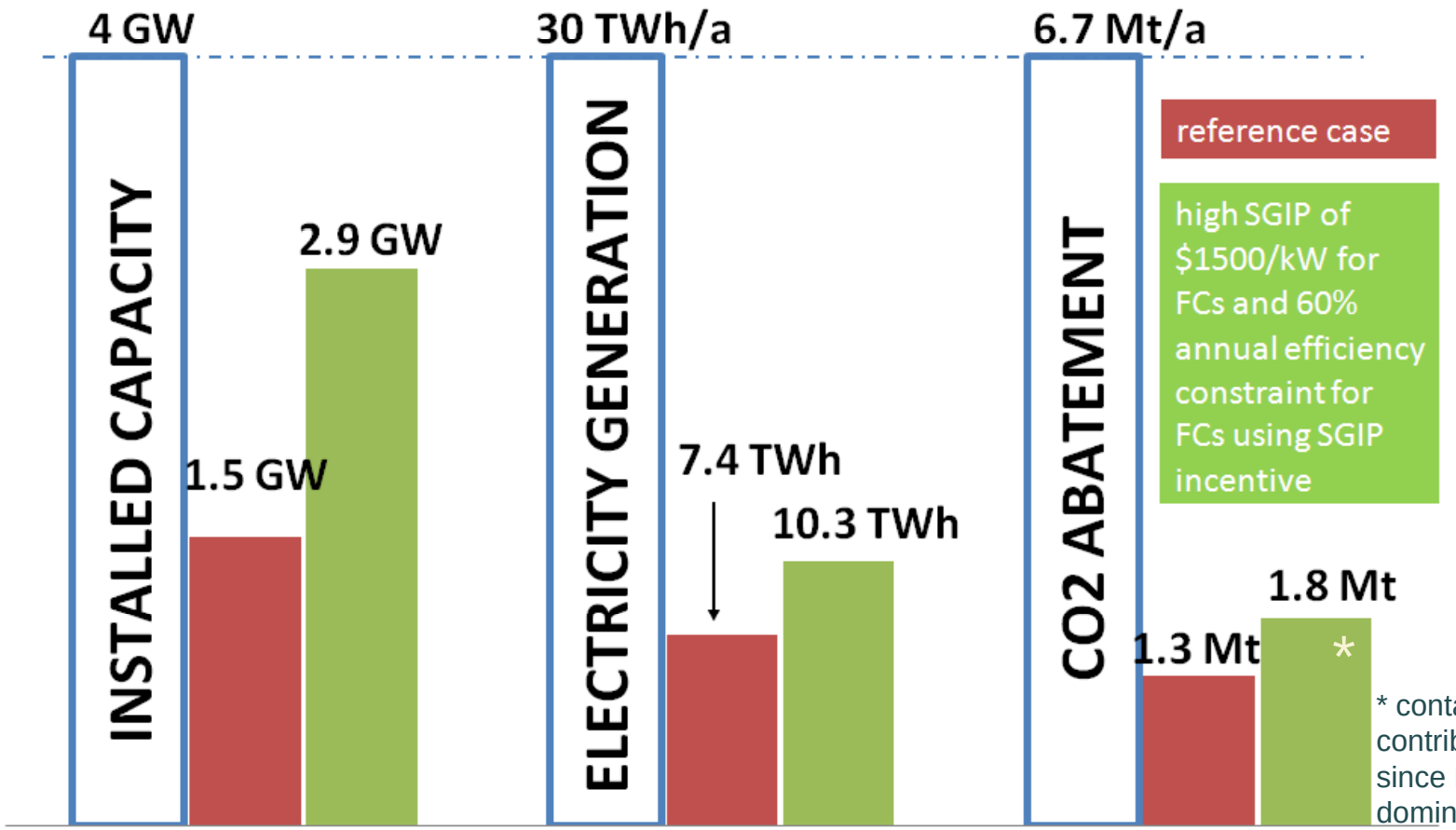
→ competition between PV / solar thermal and CHP units

Feed-in Tariff



High SGIP for FCs versus Reference Case

High SGIP: vast majority of adopted technologies are FCs with HX



* contains a negligible contribution from PV since FCs are very dominant in this case

Observations

- DER-CAM delivers highly variable capacity factors between 30% and 88% depending on the considered site and tariff
  - an average capacity factor of 55% is observed in the reference case
  - high average capacity factors of 86% assumed by ARB in scoping plan appear unrealistic
- The lower observed capacity factors impact the electricity generation from CHP considerably
- Carbon taxes drive CHP and PV / solar thermal adoption

Conclusions

- In the reference case, 1.5 GW of CHP is adopted through 2020 in this analysis of the medium-size commercial sector
  - high SGIP case raises this to 2.9 GW
- FiT slightly increases the energy output from CHP
- SGIP for FCs has a big impact
- Future work:
  - more work on appropriate FiT tariffs and impacts on adoption and capacity factors
  - interaction between PV, solar thermal, and CHP
  - effect of inclusion of storage technologies

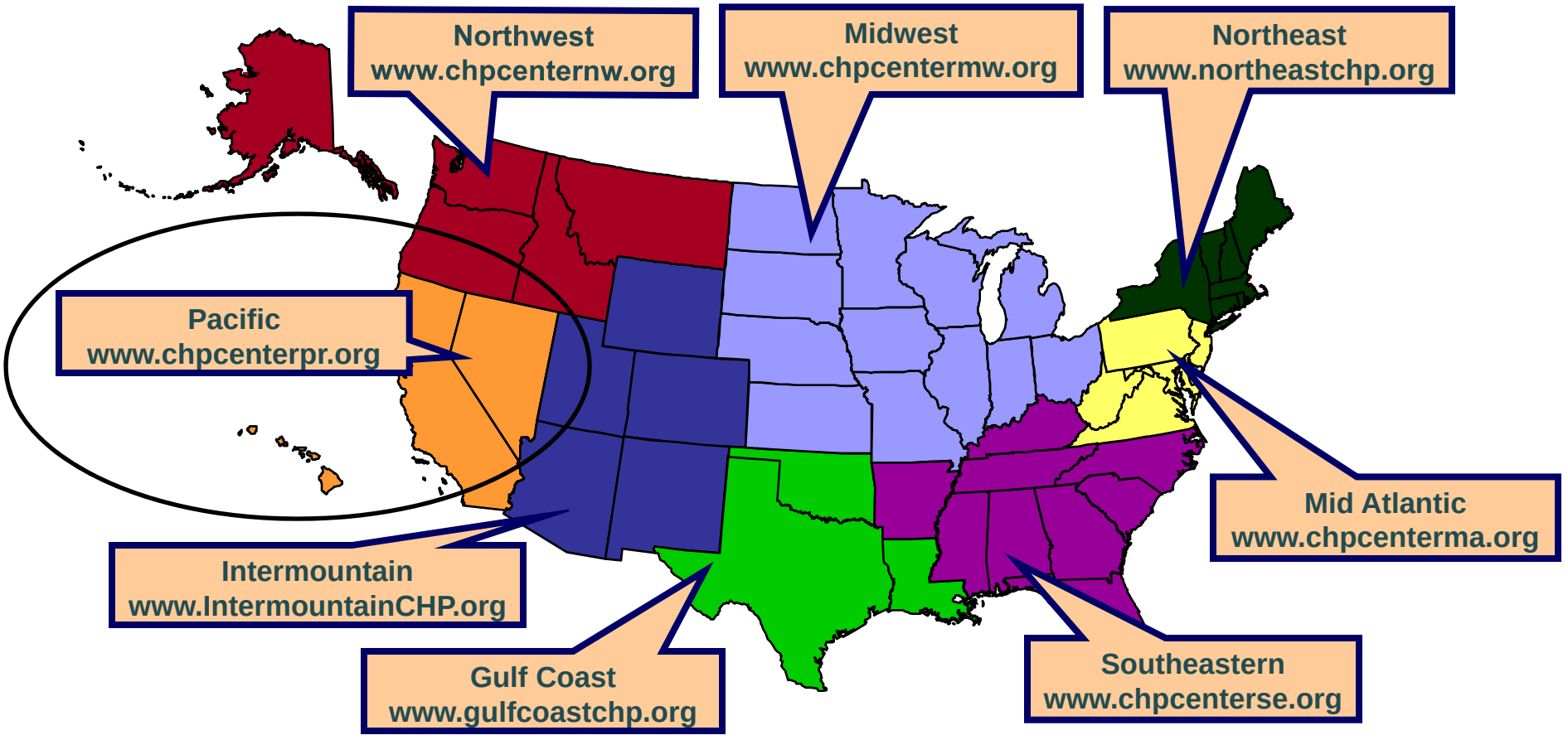
PRAC Update

PRAC Update

- PRAC is the Pacific Region Combined Heat and Power Application Center, operated by UC Berkeley, UC Irvine, and San Diego State University since 2005
- Sponsored by U.S. DOE and the CA Energy Commission, and with involvement from key partners including electric and gas utilities, Berkeley Lab, CA Clean DG Coalition, etc.
- One of eight DOE regional application centers for CHP
- Has conducted a range of educational, outreach, and direct project assistance activities to promote appropriate CHP adoption in the Pacific Region: CA, NV, HI
- PRAC: http://www.chpcenterpr.org

Regional CHP App. Centers

Promoting CHP technology and practices as well as identifying and implementing regional CHP projects



PRAC Update (cont'd)

- The PRAC team has just been awarded a three-year $1.5M continuation grant by the U.S. Department of Energy
- Proposal cost-matched (20%) by the CA Energy Commission, the Energy Biosciences Institute, and the Univ. of California
- New name for the RACs:

  "Pacific Region *Clean Energy* Application Center"
- Still a strong focus on CHP, adding also waste heat-to-power and waste/biogas power applications
- Eventual further expansion into other renewable energy and clean fuels is possible

PRAC Update (cont'd)

Workplan for the new center phase:

- maintain and expand PRAC website
- target market workshops
- waste-heat-to-energy workshop
- revised state "baseline assessment and action plan" reports
- project case study profiles
- policy roadmapping with stakeholders
- identify and facilitate high impact projects
- project management

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Thank you!

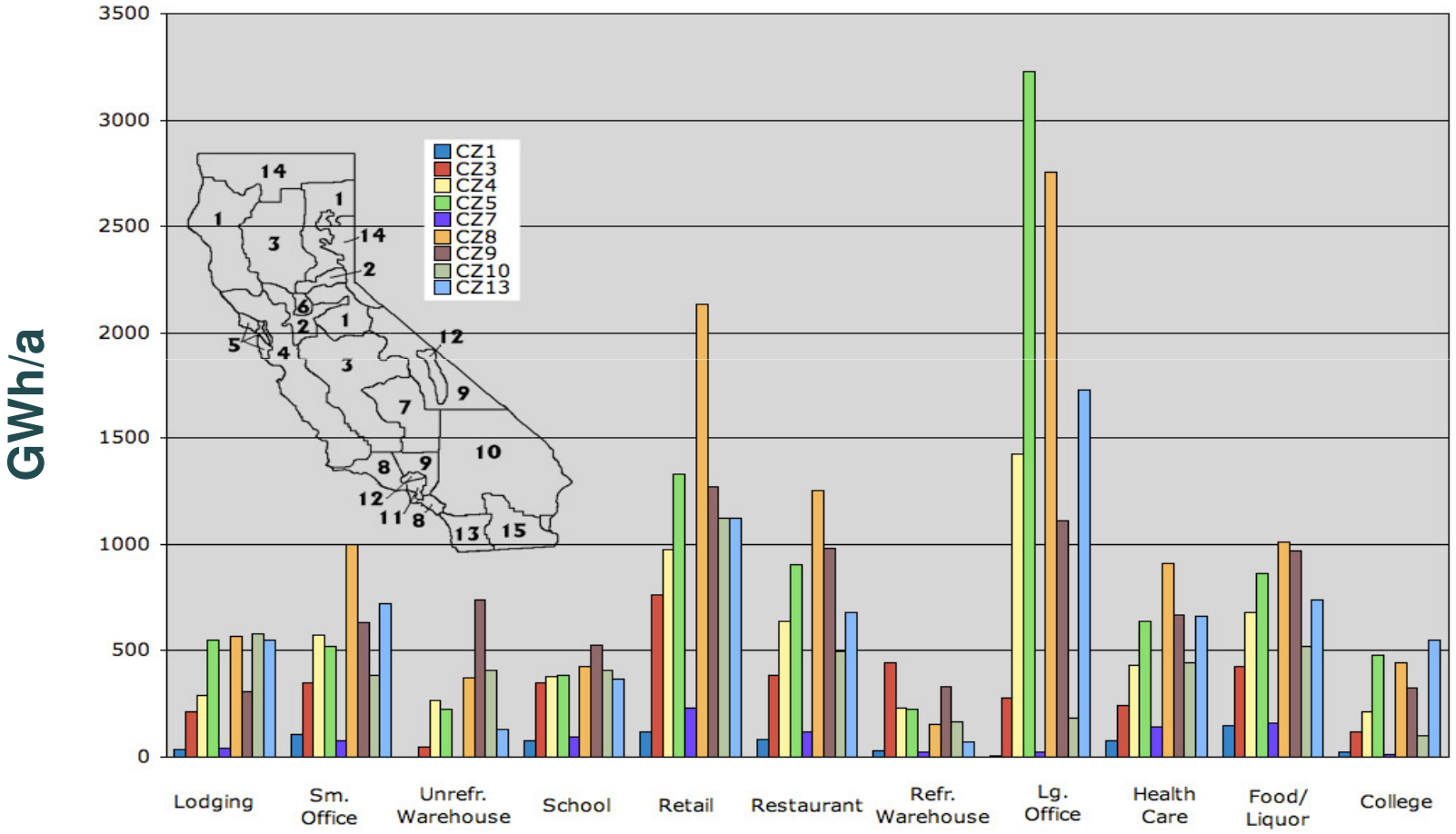
“Appendix”:
More CEUS / Result Background

End-Uses in CEUS

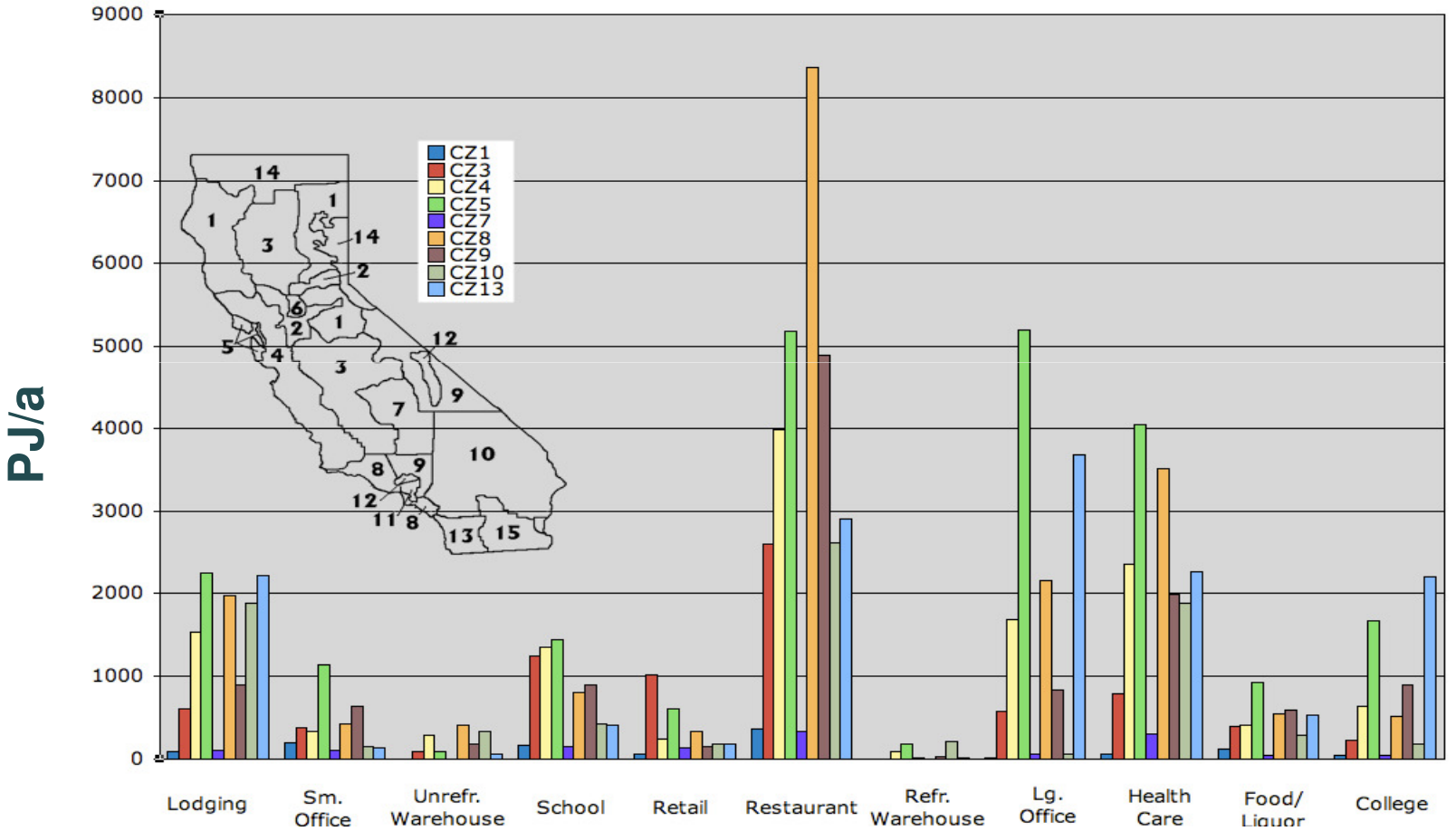
- 3 HVAC End Uses
  - Space Heating
  - Space Cooling
  - Ventilation

- 10 Non-HVAC End Uses
  - Water Heating
  - Cooking
  - Refrigeration
  - Interior Lighting
  - Exterior Lighting
  - Office Equipment
  - Miscellaneous Equipment
  - Air Compressors
  - Motors (non-HVAC)
  - Process Equipment

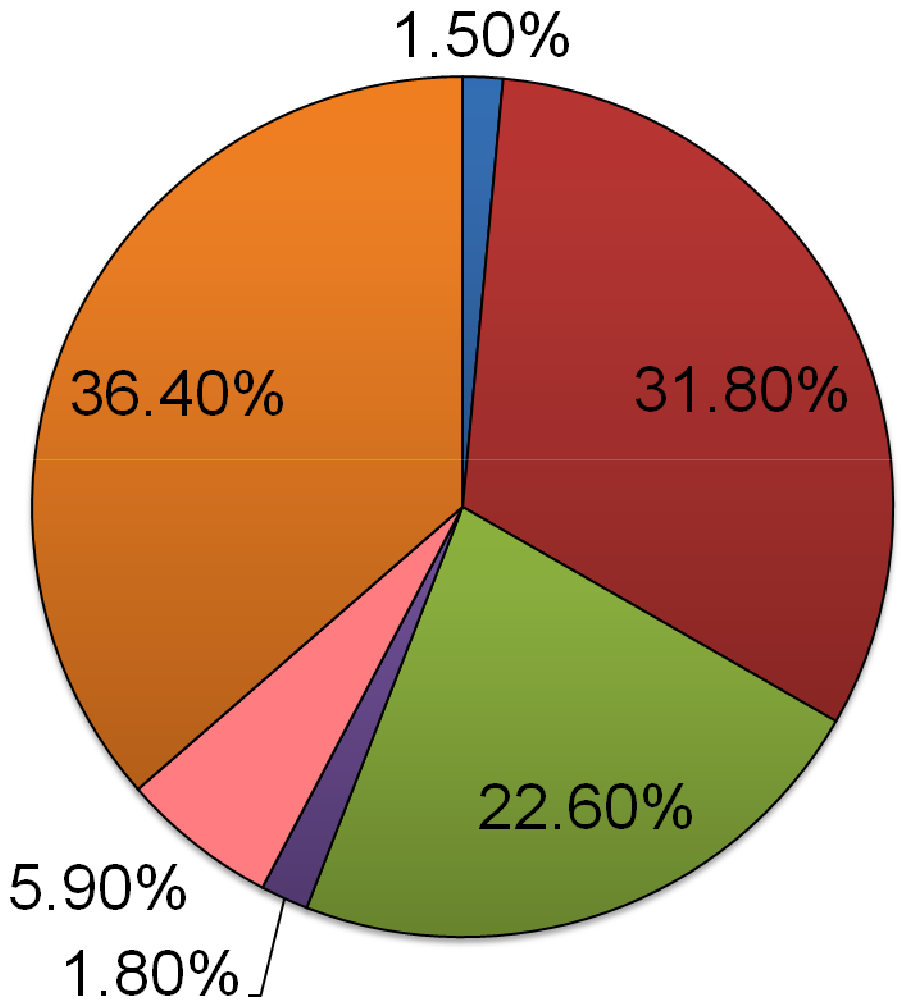
Annual Electricity Use by Building Types and Zones (CEUS)



Annual Natural Gas Use by Building Types and Zones (CEUS)



NG by End Use in CEUS



Considered Blg. Types

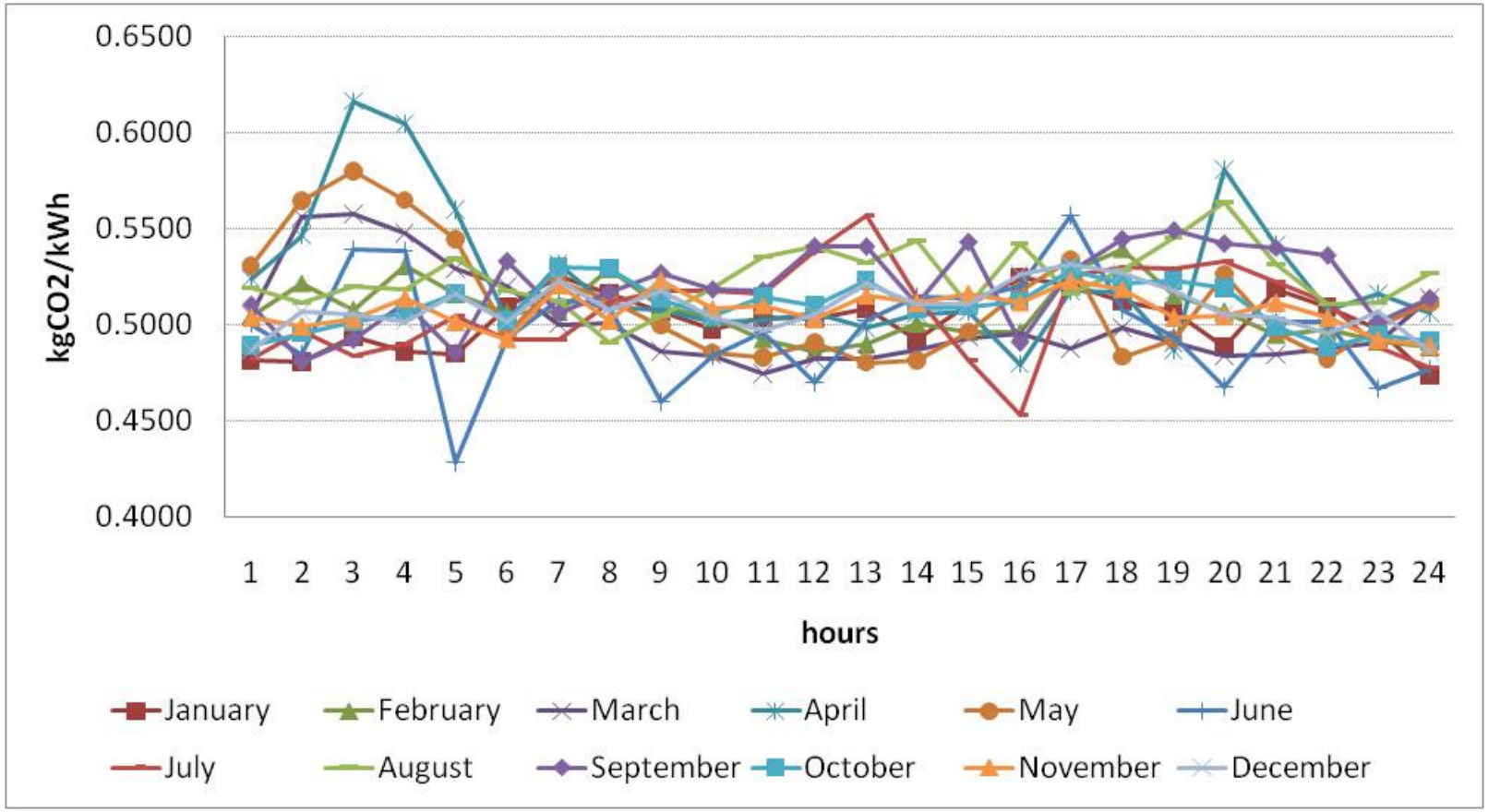
	Small Office			Large Office			Restaurant			Retail Store			Food/Liquor			Un. Warehouse		
TOTAL	1			25			1			9			9			7		
Zone	S	M	L	S	M	L	S	M	L	S	M	L	S	M	L	S	M	L
FCZ 01				☆	☆							☆			☆			
FCZ 03				☆	☆	☆						☆			☆			☆
FCZ 04			☆	☆	☆	☆			☆			☆			☆			☆
FCZ 05				☆	☆	☆						☆			☆			☆
FCZ 07				☆	☆	☆						☆			☆			
FCZ 08				☆	☆	☆						☆			☆			☆
FCZ 09				☆	☆							☆			☆			☆
FCZ 10				☆	☆	☆						☆			☆			☆
FCZ 13				☆	☆	☆						☆			☆			☆

	School			College			Health Care			Hotel			Misc			Ref. Warehouse			
TOTAL	18			18			17			16			0			17			
Zone	S	M	L	S	M	L	S	M	L	S	M	L	S	M	L	S	M	L	TOTAL
FCZ 01		☆	☆		☆	☆		☆	☆			☆					☆		12
FCZ 03		☆	☆		☆	☆		☆	☆		☆	☆					☆	☆	16
FCZ 04		☆	☆		☆	☆		☆	☆		☆	☆					☆	☆	18
FCZ 05		☆	☆		☆	☆			☆		☆	☆					☆	☆	15
FCZ 07		☆	☆		☆	☆		☆	☆			☆					☆	☆	14
FCZ 08		☆	☆		☆	☆		☆	☆		☆	☆					☆	☆	16
FCZ 09		☆	☆		☆	☆		☆	☆		☆	☆					☆	☆	15
FCZ 10		☆	☆		☆	☆		☆	☆		☆	☆					☆	☆	16
FCZ 13		☆	☆		☆	☆		☆	☆		☆	☆					☆	☆	16
																	TOTAL		138

optimizations take up to 10 hours

Marginal Macrogrid CO_2 Emission Rates in 2020

used for the whole state (except **run M-hc,** see following slides)



source: Developing a Greenhouse Gas Tool for Buildings in California: Methodology and Use, Amber Mahone, Snuller Price, William Morrow, Energy and Environmental Economics, Inc., September 10, 2008 and PLEXOS Production Simulation Dispatch Model.

Tariffs

- **PGE**
  - electric peak load 0 – 199 kW: flat tariff A-1, no demand charge, seasonal difference between winter and summer months of a factor of 1.45
  - electric peak load 200 kW – 499 kW: TOU tariff A-10, seasonal demand charge
  - Electric peak load 500 kW and above: TOU tariff E-19, seasonal demand charge
- **SCE**
  - electric peak load 20 – 200 kW: flat tariff GS-2, no demand charge, seasonal difference between winter and summer months of a factor of 1.1
  - electric peak load 200 kW – 500 kW: tariff TOU-GS-3, seasonal demand charge
  - electric peak load 500 kW and above: tariff TOU-8, seasonal demand charge
- **SDGE**
  - The same electricity rate is uses for all simulations, AL-TOU. The main difference is that fixed cost is higher for above 500kW than below.

Sources: PGE tariffs effective March 1 2009, SCE tariffs effective February 9 2009, SDGE tariffs effective January 1 2009
A-1: http://pge.com/tariffs/tm2/pdf/ELEC_SCHEDS_A-1.pdf
A-10: http://www.pge.com/tariffs/tm2/pdf/ELEC_SCHEDS_A-10.pdf
E-19: http://www.pge.com/tariffs/tm2/pdf/ELEC_SCHEDS_E-19.pdf
GS-2: http://www.sce.com/NR/sc3/tm2/pdf/ce30-12.pdf
TOU-GS-3: http://www.sce.com/NR/sc3/tm2/pdf/CE281.pdf
TOU-8: http://www.sce.com/NR/sc3/tm2/pdf/ce54-12.pdf
AL-TOU: http://www.sdge.com/tm2/pdf/ELEC_ELEC-SCHEDS_AL-TOU.pdf

Sensitivity Runs

18 different scenarios have been performed so far for the midsize commercial sector

- **L**ow NG prices in 2020, spring 2009 NG prices are kept constant in real terms, SGIP of $500/kW for FCs, **run L**
- **H**igh natural prices in 2020, maximum NG prices in 2008 are kept constant in real terms, SGIP of $500/kW for FCs, **run H**
- **M**edium NG prices in 2020, average of the NG prices between January 2006 and March 2009 are constant in real terms, SGIP of $500/kW for FCs, **run M , "Reference Case"**
- **M**edium NG prices in 2020 and **h**igher marginal **c**arbon emission rates during off-peak hours in southern CA, SGIP of $500/kW for FCs, **run M-hc** (marginal CO_2 rate during off-peak hours of 0.7883kgCO2/kWh, Marnay, C. et al., "Estimating Carbon Dioxide Emissions Factors for the California Electric Power Sector", Lawrence Berkeley National Laboratory Report LBNL 49945, Aug.2002.)

Sensitivity Runs

- **M**edium NG prices in 2020 and **h**igher marginal **c**arbon emission rates during off-peak hours in southern CA and **SGIP** incentive of $750/kW for FCs, **run M-hc-SGIP**

- **M**edium NG prices in 2020 and **no min**. load constraint, SGIP of $500/kW for FCs, **run M-no-min** (for all other runs a minimum load constraint of 0.5 is imposed and the engines cannot operate with less than 50% nameplate capacity)

- **M**edium NG prices in 2020 and **only FC**s are allowed, SGIP of $500/kW for FCs, **run M-onlyFC**

- **M**edium NG prices in 2020, **h**igh **c**arbon emissions in Southern CA, **no PV** and **no solar** thermal, SGIP of $500/kW for FCs, **run M-hc-noPVSolar**

Sensitivity Runs

do-nothing	run L	run H	run M	run M-hc	run M-hc-SGIP	run M-no-min	run M-onlyFC	run M-hc-noPVSolar
total annual costs (M$)	4859.7	5381.8	5030.8	5030.8	5030.8	5030.8	5030.8	5030.8
total annual CO2 emissions (Mt/a)	19.7	19.7	19.7	21.4	21.4	19.7	19.7	21.4

invest cases	run L	run H	**run M Reference Case**	run M-hc	run M-hc-SGIP	run M-no-min	run M-onlyFC	run M-hc-noPVSolar
total annual costs (M$)	4103.6	5257.0	4837.9	4837.9	4836.1	4838.7	4921.1	4857.6
total annual CO2 emissions (Mt/a)	18.5	18.7	18.4	19.7	19.7	18.4	18.5	20.0
total installed capacities (without PV) (GW)	4.7	0.1	1.5	1.5	1.5	1.6	0.7	1.5
total electricity produced by DG (without PV) (TWh)	24.1	0.4	7.4	7.4	7.4	7.4	3.7	7.4
total cooling offset (TWh)	2.2	0.0	0.4	0.4	0.4	0.4	0.0	0.4
changed costs compared to do-nothing (%)	-15.6	-2.3	-3.8	-3.8	-3.9	-3.8	-2.2	-3.4
changed CO2 compared to do-nothing (%)	-6.2	-4.9	-6.7	-8.0	-8.0	-6.7	-6.1	-6.4
average capacity factor DG (without PV) (%)	58.8	55.5	54.9	54.9	55.0	53.0	63.6	57.9

Sensitivity Runs

- **M**edium NG prices in 2020 and a **4% i**nterest rate, SGIP of $500/kW for FCs, **run M-4%i**

- Six different carbon tax runs with and without PV / solar thermal as possible option, SGIP of $500/kW for FCs
  - $150/tC (= $40.1/$tCO_2$), **run M-lowCtax; run M-lowCtax-noPVSolar**
  - $450/tC (= $122.7/$tCO_2$), **run M-medCtax; run M-medCtax-noPVSolar**
  - $1000/tC (= $272.7/$tCO_2$), **run M-highCtax; run M-highCtax-noPVSolar**

- **M**edium NG prices in 2020 and a **F**eed-**i**n **T**ariff which reflects the whole purchase tariff, the feed-in tariff applies to all DG technologies, no SGIP, **run M-FiT** (constraint: purchase > sales; this constraint is needed otherwise some sites would install CHP without limits. This can drive the energy conversion efficiency near the macrogrid efficiency of ca. 34% since most of the waste heat could not be utilized)

Sensitivity Runs

- **M**edium NG prices in 2020 and a **F**eed-**i**n **T**ariff which reflects the whole purchase tariff, the feed-in tariff applies to all CHP technologies, **no PV** and no **solar**, no SGIP, **run M-FiTnoPVSolar** (constraint: purchase > sales)

- **M**edium NG prices in 2020 and a high SGIP incentive of $1500/kW (=60% of the 2008 incentive value) for FCs and a 60% annual efficiency constraint for FCs using SGIP, **run M-SGIP60%**

- **M**edium NG prices in 2020 and a **F**eed-**i**n **T**ariff which reflects the **g**eneration component of the tariff, the feed-in tariff applies to all DG technologies, no SGIP, **run M-FiTg**

- **M**edium NG prices in 2020 and a **F**eed-**i**n **T**ariff using the MPR and TOD, **run M-MPR,** some technical problems / issues needs to be resolved

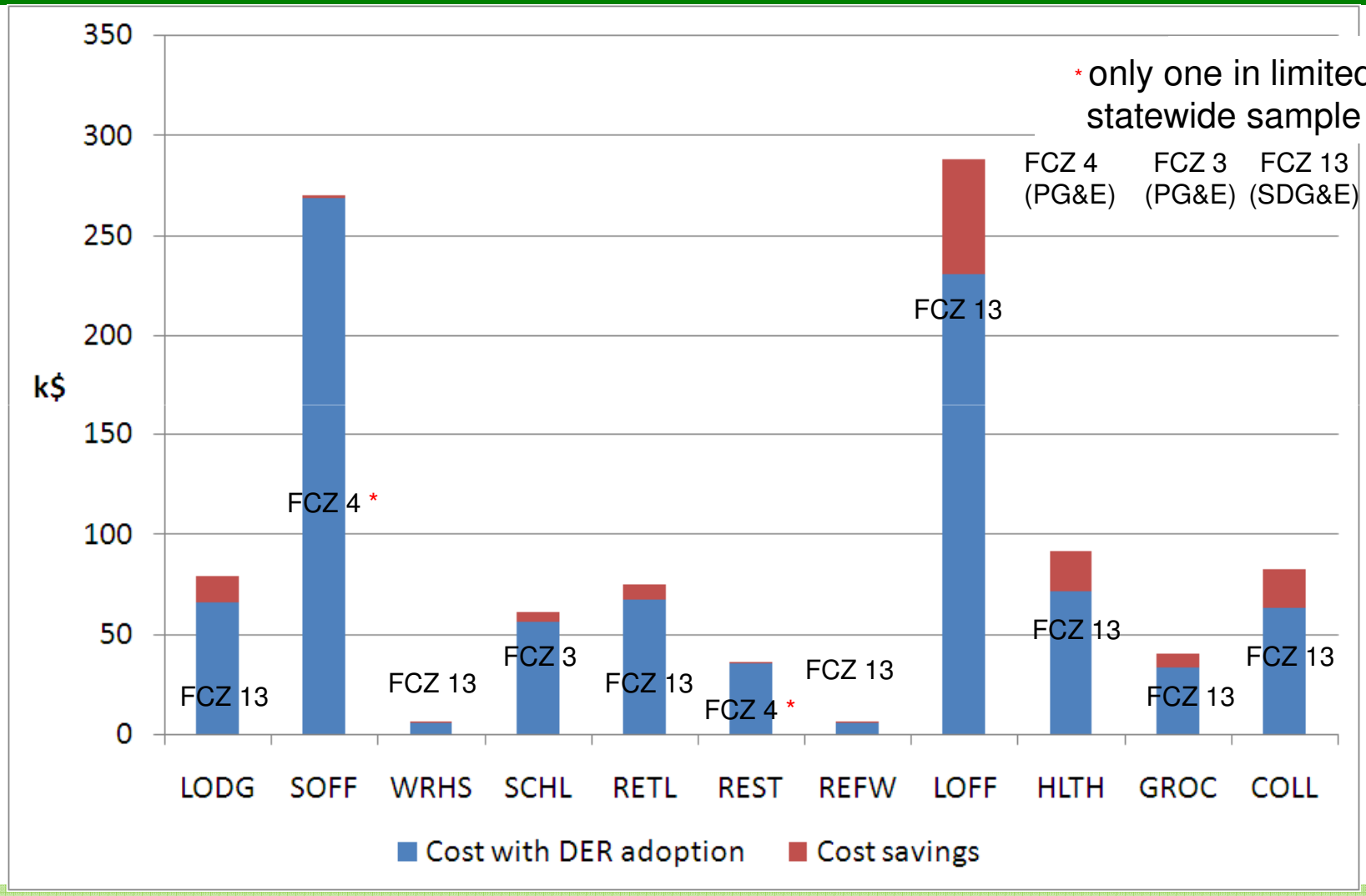
in all runs electricity tariffs (for purchase) from early 2009 / late 2008 are used and constant in real terms

Sensitivity Runs

do-nothing	run M-4%i	run M-lowCtax	run M-lowCtax -noPVSolar	run M-medCtax	run M-medCtax -noPVSolar	run M-highCtax	run M-highCtax -noPVSolar	run M-FiT	run M-FiT noPVSolar	run M-SGIP60%
total annual costs (M$)	5030.8	5837.4	5837.4	7449.0	7449.0	10408.1	10408.1	5030.8	5030.8	5030.8
total annual CO2 emissions (Mt/a)	19.7	19.7	19.7	19.7	19.7	19.7	19.7	19.7	19.7	19.7

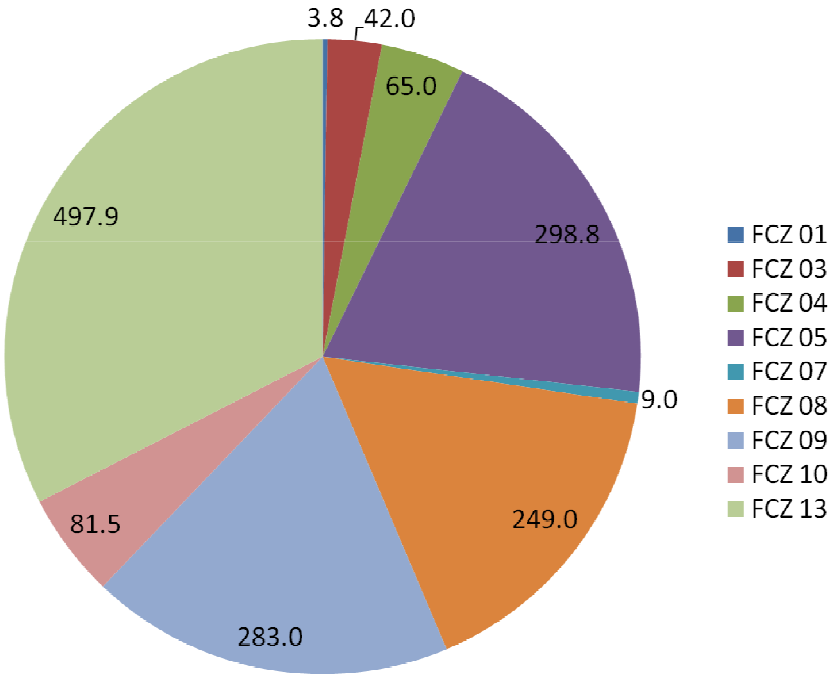
invest cases	run M-4%i	run M-lowCtax	run M-lowCtax -noPVSolar	run M-medCtax	run M-medCtax -noPVSolar	run M-highCtax	run M-highCtax -noPVSolar	run M-FiT	run M-FiT noPVSolar	run M-SGIP60%
total annual costs (M$)	4757.0	5574.5	5624.5	6885.8	7147.2	9068.2	9934.4	4828.0	4848.9	4706.9
total annual CO2 emissions (Mt/a)	17.5	17.8	18.7	15.2	18.6	13.9	18.0	18.2	18.7	17.9
total installed capacities (without PV) (GW)	1.4	1.4	1.5	1.5	1.7	1.5	2.2	1.5	1.6	2.9
total electricity produced by DG (without PV) (TWh)	7.4	7.3	7.5	6.4	8.1	7.0	10.7	7.5	8.0	10.3
total cooling offset (TWh) :	0.4	0.4	0.4	0.2	0.4	0.1	0.2	0.4	0.5	0.6
changed costs compared to do-nothing (%)	-5.4	-4.5	-3.6	-7.6	-4.1	-12.9	-4.6	-4.0	-3.6	-6.4
changed CO2 compared to do-nothing (%)	-10.9	-9.9	-5.2	-22.9	-5.6	-29.2	-8.5	-7.8	-5.1	-9.3

Cost Savings – Best Bldgs.
(Reference Case)

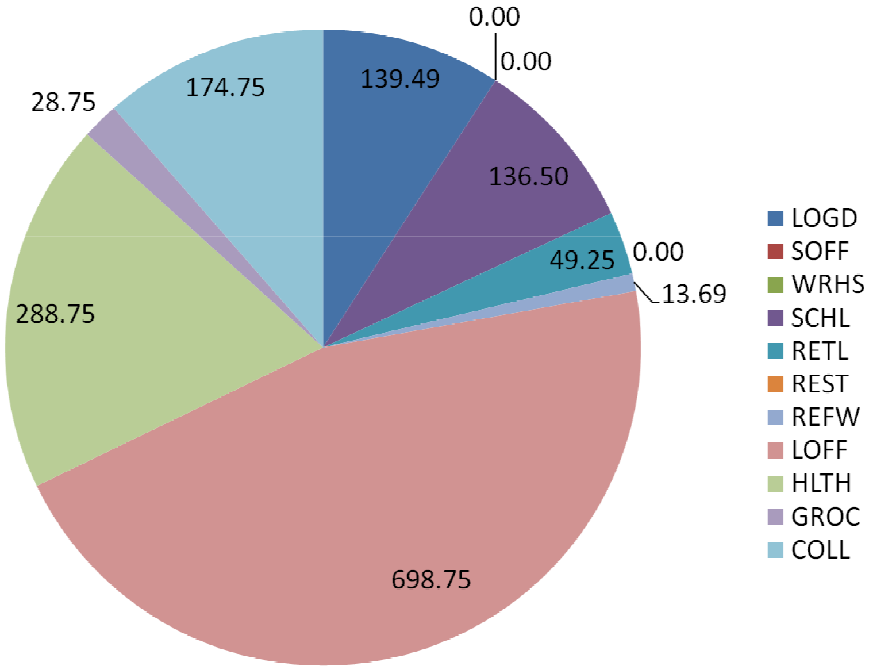


Installed Capacity (MW)
(Reference Case)

By Climate Zone



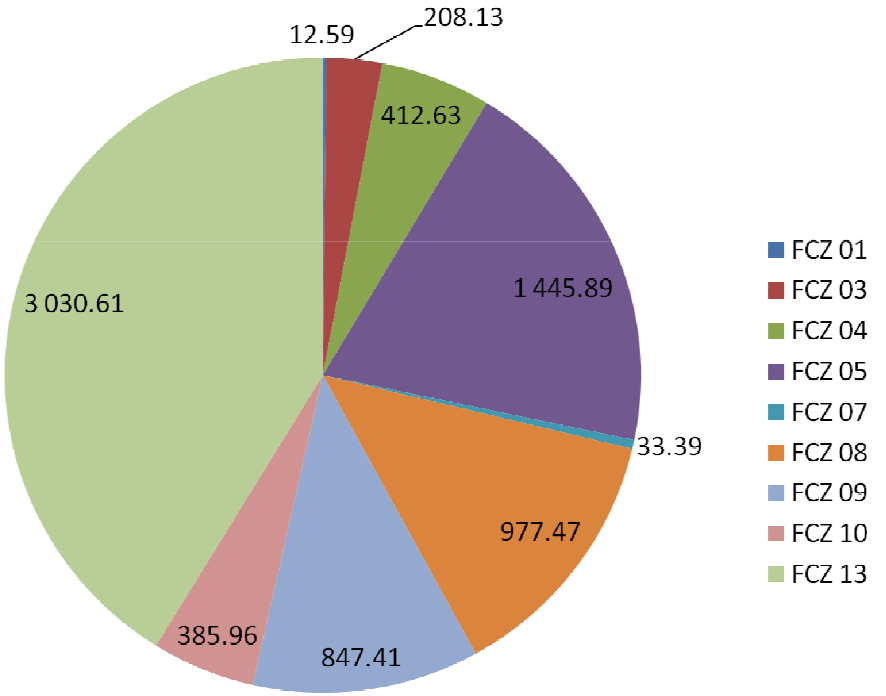
By Building Type



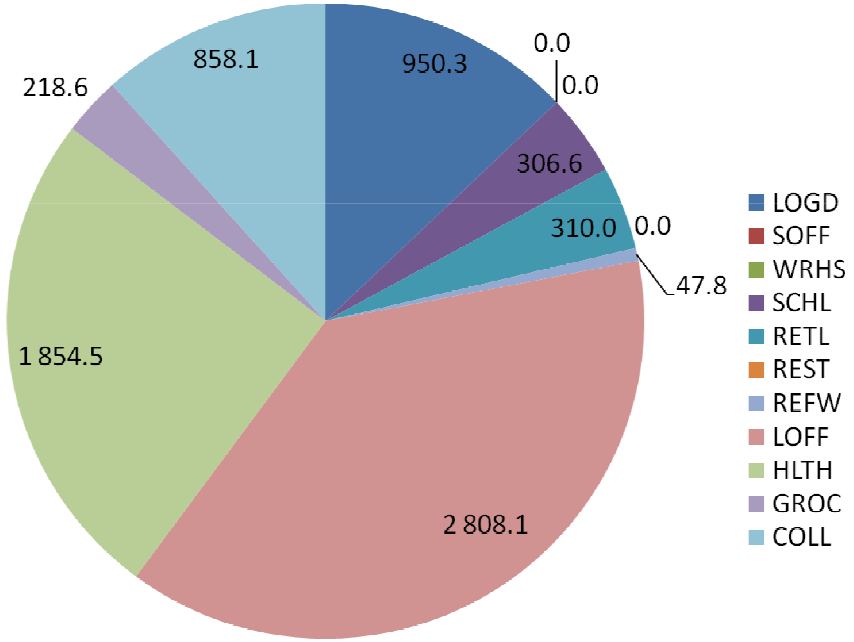
Total installed capacity in limited statewide = 1.5 GW

On Site Generation (GWh/a)
(Reference Case)

By climate zone



By building type



Total on site generation in limited statewide = 7.4 TWh