From Zero Energy to Zero Emissions
The Transition to Carbon as an Efficiency Metric
2019 RESNET Building Performance Conference
New Orleans, LA
February 25, 2019
CA Building Energy Policy

February 25, 2019

Martha Brook, P.E.
Advisor to Commissioner McAllister
2018 Global Surface Temperature Anomalies Relative to 1961-1990 Average
1850-2018 Global Surface Temperature Anomalies relative to 1961-1990 average

reddit/dataisbeautiful/neilkaye
Senate Bill 350
The Clean Energy and Pollution Reduction Act of 2015

- EE: Double energy efficiency savings by 2030
- Renewables: 50% renewable energy by 2030
- Equity: Address barriers for low-income residents & disadvantaged communities
- EVs: Encourage widespread transportation electrification
- IRPs: Integrated resource planning to reduce greenhouse gas emissions
Senate Bill 100
The 100 Percent Clean Energy Act of 2018

- **RPS:**
  - 33% by 2020
  - 50% by 2025
  - 60% by 2030

- Zero-carbon resources supply 100 percent of all retail sales of electricity to California end-use customers
Executive Order B-55-18

To Achieve Carbon Nutrality

- Carbon Neutral as a State Across all Sectors by 2045
Energy Use Reductions needed to meet SB 350
Energy Savings (Quad BTUs)

SB350 Doubling Goal

*“Other” includes federal appliance standards; local government ordinances; air quality districts; Proposition 39; industrial and agricultural sectors; Behavioral, Retrocommissioning, Operational Energy Efficiency (BROs); benchmarking; energy asset rating; smart meter and controls; & electrification.
Impacts, Risks, and Adaptation in the United States:
Fourth National Climate Assessment
CA GHG Emissions

- Transportation: 26%
- Industry: 37%
- Agriculture: 9%
- Buildings: 27%
Policy Direction: Building Decarbonization

• First significant policy discussion - *2018 Integrated Energy Policy Report Update* (see [Decarb Docket Log](#))
  - *Zero Emission Buildings policy goals, rather than ZNE*

• *2018 legislation*: new construction & upstream product incentives (SB 1477), plans to meet statewide building decarb targets (AB 3232), 100% RPS (SB 100)

• *Governor Brown Executive Order*: Carbon Neutrality by 2045

• Several cities working on decarbonization reach codes for 2020
2016 Energy Use in California Buildings (MMBtu)

- **Natural Gas** (48%)
  - Residential: 429,751,048
  - Commercial: 197,812,601

- **Electricity** (52%)
  - Residential: 310,115,814
  - Commercial: 358,225,905
Electricity CO₂ Intensity

Electric Emissions (Tons/MWh), 2019-2030
Buildings Perspective: 2019

Emissions Intensity Relative to Natural Gas
Buildings Perspective: 2030

Emissions Intensity Relative to Natural Gas

[Heat map showing emissions intensity by hour and month, with varying shades from green to red indicating different intensities.]
CZ 3 2019 Std – 2100 sf

Annual 2030 GHG (kg)

- Gas
  - Space Heat
- Gas
  - Water Heat
- Elec
  - Space Heat
  - Water Heat

1 ton
Policy Direction: Building Standards

- Adopt an **energy** metric that aligns with GHG emissions (applied to all fuel types)
- Adopt a secondary **demand flexibility** metric (applied only to electricity)
- Implement performance trade-offs that prioritize & protect the building envelope
- Address refrigerant leakage emissions
Policy Direction: Existing Buildings

• SB 1477: Low-emissions buildings and sources of heat energy

• AB 3232 building decarbonization focus will be prevalent in 2019 existing building action plan update

• Identify where code can be leveraged
From Zero Energy to Zero Emissions
The Transition to Carbon as an Efficiency Metric
2019 RESNET Building Performance Conference

Nic Dunfee
Senior Project Manager

New Orleans, LA
February 25, 2019
Agenda

- Keys to Decarbonization
  - On-Site Combustion: *It’s Not What It Used to Be*
  - Renewable Portfolio Standards: *The Future of the Grid*
  - Decarbonization in the Home
The Need to Decarbonize

“Pathways limiting global warming to 1.5°C with no or limited overshoot would require rapid and far-reaching transitions in energy, land, urban and infrastructure (including transport and buildings), and industrial systems.”

“These systems transitions are unprecedented in terms of scale, but not necessarily in terms of speed, and imply deep emissions reductions in all sectors, a wide portfolio of mitigation options and a significant upscaling of investments in those options.”

“Avoiding overshoot and reliance on future large-scale deployment of carbon dioxide removal (CDR) can only be achieved if global CO2 emissions start to decline well before 2030.”
Three Keys to Decarbonization

More Renewables
Make our energy cleaner

Beneficial Electrification
Make use of the cleanest energy source available

Energy Efficiency
Use less energy
The Building Decarbonization Coalition is a 501(c)(3) nonprofit organization whose mission is to convene the stakeholders necessary to drive the conversation around building decarbonization at the state level. The Coalition brings together industry, advocacy, government experts, and the private sector to develop integrated and effective approaches to make decarbonization a reality.

http://www.buildingdecarb.org/
BDC Road Map Recommendations

- California should adopt a Zero Emission Building Code as a State
- California should set greenhouse gas emission reduction standards for the overall building stock that account for emissions lock-in from fossil fuel-powered appliances
- California should build the market share for underlying technologies
BDC Recommendations

California should adopt a Zero Emission Building Code as a State

2025

- All Residential New Construction

2028

- All Commercial New Construction
BDC Recommendations

California should set greenhouse gas emission reduction standards for the overall building stock that accounts for emissions lock-in from fossil fuel-powered appliances.

2025
20% GHG reductions from building sector

2030
40% GHG reductions from building sector

2045
100% GHG reductions from building sector
BDC Recommendations

http://www.buildingdecarb.org/resources/a-roadmap-to-decarbonize-californias-buildings
California should build the market share for underlying technologies:

Heat Pump Space and Water Heating

- **2025**: 50% of statewide sales
- **2030**: 100% of statewide sales
Water Heating

Increase the share of high efficiency heat pumps for water heating from 1% of sales in 2018, to 50% in 2025 and 100% in 2030.

http://www.buildingdecarb.org/resources/a-roadmap-to-decarbonize-californias-buildings
Space Heating

Increase the share of high efficiency heat pumps for space heating from 5% of sales in 2018, to 50% in 2025 and 100% in 2030.

http://www.buildingdecarb.org/resources/a-roadmap-to-decarbonize-californias-buildings
On-Site Combustion: It’s Not What It Used to Be

Natural Gas Distribution Plant

- $T =$ therms leaving gas plant
- $T =$ therms combusted at power plant
- $TDG =$ therms transmission losses
- $G =$ therms delivered to site

These are the same therm. Combusted on site or at the source, it creates the same GHGs.

Electrical Power Plant

- $HR =$ power plant heat rate (therm/kWh)
- $e =$ kWh produced, accounting for renewables
- $E =$ kWh delivered to site

Renewable Generation

- $RPS =$ Renewable Portfolio Standard, the percent of power generated by renewables
- $TDE =$ kWh transmission losses

Home
Renewable Portfolio Standards

- **29 states** currently have RPS regulations or mandates

**Source:** Berkeley Lab (November 2018)
Source Carbon Content: 2018

- 117 lb CO₂/MMBTU
- 100 Therms Delivered to Power Plant Or Home
- 2,842 kWh (9.7 mmBTU) (97 therms)
- 100 Therms Delivered to Power Plant Or Home
- 88 kWh (3 therms)

Power Plant
- 1.648 kWh
- 88 kWh (3 therms) Power Plant Losses
- 1,648 kWh
- 1.0 Therm = 18.51 kWh

Transmission Lines
- 1,282 kWh
- 603 kWh 32% RPS

Electricity Delivered to Home
- 1,851 kWh (6.3 MMBTU)

Transmission Losses
- 1,851 kWh
- 34 kWh

Home
- 1.851 kWh (6.3 MMBTU)

Gas Transmission Losses
- 88 kWh (3 therms)
117 lb CO₂/ MMBTU

100 Therms Delivered to Power Plant

Power Plant

1,648 kWh

57% Power Plant Losses

88 kWh (3 therms) Gas Transmission Losses

1.0 Therm = 32.45 kWh

11 years

the electric grid will be cleaner than using natural gas in California.

A home can easily last is well over 100 years.

105 lb CO₂/ MMBTU

57% Power Plant Losses

1,648 kWh

Electricity Delivered to Home

3,147 kWh

60% RPS

1,282 kWh

1,923 kWh

In 11 years the electric grid will be cleaner than using natural gas in California.
An inefficient heat pump delivers 300% effective energy use. Today, an all-electric home produces less carbon than a home using natural gas in California.

A more common 400% effective energy use HP = 44 lb CO₂ / MMBTU
The Hardest Habits to Break

People care that they are comfortable and have hot water, they don’t care what fuel source makes these happen.

The only place most people interact with their fuel source is cooking – it is the hardest for them to give up.

Gas burners were estimated to add 25–33% to the week-averaged indoor NO₂ concentrations during summer and 35–39% in winter... For CO, gas stoves were estimated to contribute 30% and 21% to the indoor air concentration in summer and winter, respectively.

LBNL

Carbon monoxide is a deadly toxin. In one study, 51 percent of kitchen ranges tested raised CO concentrations in the room above the EPA standard of 9 parts per million. Five percent had carbon monoxide levels above 200 parts per million.

Iowa State
The Hardest Habits to Break

Induction cooking is the future!

- No combustion
- Cooking surface is not directly heated
- Better temperature
- Faster cooking
  (95% effective; natural gas only 35% effective)
- Easy to clean
Thank You

Nic Dunfee,
Senior Project Manager

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CALIFORNIA DREAMIN’
PATH TO NET ZERO ENERGY HOMES
CALIFORNIA ZERO-NET-ELECTRICITY
NEW HOMES ENERGY CODE

RESNET CONFERENCE
FEBRUARY 2019
NEW ORLEANS, LOUISIANA

PIERRE DELFORGE AND DAVID B. GOLDSTEIN, PH.D.
NATURAL RESOURCES DEFENSE COUNCIL
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CA has ambitious climate goals, but no explicit policy pathway to zero-emissions buildings yet

- 40% GHG reduction by 2030
  - SB 32 (2016)

- Electric sector:
  - 60% renewable by 2030
  - 100% carbon-free by 2045
  - SB 100 (2018)

- Carbon neutrality by 2045

- 40% GHG reductions in buildings by 2030 (assessment)
  - AB 3232

- $200M incentives for low-emissions buildings and equipment
  - SB 1477
Regulators Have Agreed on Zero Energy Goals and Timetables

- Back in 2008 the California Energy Commission and the California Public Utilities Commission agreed to a goal of Zero Net Energy (ZNE) buildings:
  - Residential by 2020
  - Commercial by 2030
- This agreement spurred the Energy Commission to achieve greater reductions in energy use in the last four code cycles than had been the case before.
- Most recent (2019) residential code requires “zero net electricity”.
  - Solar is part of the prescriptive requirements
“Nothing is Better Than Zero”

– Zero Net Energy (ZNE) does not necessarily mean zero energy bills

– After Zero Net Energy facilities--or even stand-alone solar and wind energy--become common, Zero Net Energy does not mean zero emissions from the grid

– But the 2019 Title 24 takes steps in the direction of zero emissions
Title 24 2019 Residential: Key Advances

- **Energy Efficiency**
  - ✓ Solar/EE tradeoff now only for solar+battery. EE tradeoff limited to 2016 code EE requirements
  - ✓ High-performance walls, attics, windows, QII

- **Independent gas and electric baselines for low-rise residential (similar to RESNET)**
  - ✓ Level-playing field electric vs. gas

- **Electric water heating ready**
  - ✓ 240V dedicated outlet + breaker space in panel

- **Variable capacity heat pumps**
  - ✓ More favorable modeling in software (work-in-progress ACM)

- **Heat pump water heater thermal storage**
  - ✓ Credit for load shifting capability (work-in-progress ACM)
“Zero Net Electricity”

- Code only requires solar to offset as much electricity use (TDV) as mixed-fuel prototype
- Same for all-electric buildings (no solar “penalty” for going all-electric)
- Does NOT offset gas use (cost-effective constraints)
- Can add more solar than code minimum, but no compliance credit for the extra
- Also limited by CPUC connection rule
- Flexibility for solar: purchased, PPAs, lease, community solar
Electric Heat Offers Pathway To Zero Emissions

Annual Greenhouse Gas Emissions from Energy Use of Title 24 2019-Compliant Building

NRDC analysis, climate zone 13 (Fresno) with rooftop solar. Including methane leakage
How about power plant emissions: Is electric heat really cleaner than gas heat?

Total electricity Emissions

<table>
<thead>
<tr>
<th>Year</th>
<th>Total electricity emissions</th>
</tr>
</thead>
<tbody>
<tr>
<td>2020</td>
<td>1.9 MT CO2e</td>
</tr>
<tr>
<td>2045</td>
<td>ZERO</td>
</tr>
</tbody>
</table>

Gas furnace
- 80% eff.
- Combustion: 2.0 MT CO2e
- Methane leakage (2.3%*): 1.6 MT CO2e
- Total gas emissions: 3.6 MT CO2e

Heat pump
- 300% eff.
- 30 MMBTU heat
- Total electricity emissions: 1.1 MT CO2e

NRDC calculations, climate zone 13 Fresno

* Alvarez A. et al, Science, 2018
Title 24 2019 Residential: Remaining Issues

• No longer penalizes all-electric, but still does not encourage it as the lowest emissions option
  – Still gas baseline for multi-family with central DHW and recirc.
• No standards for air-tightness (now different than RESNET)
• Inability to model central HPWH
Title 24 2019 Non-Residential: Remaining Issues

- No mid-/high-rise multi-family prototype
- Same-fuel baseline for HVAC and DHW
- Issues with temperature maintenance in water heating loop modeling
- Heat loss from recirc not captured
- Return water temperature effect on COP/AFUE not captured
- DHW thermal storage modeling capability
- Inability to model air-tightness
What about net zero emissions?

- As noted net zero energy equals net zero carbon only for a grid with minimal variable-output renewable energy sources. If most facilities achieve ZNE, this equality ceases to be the case:
  - Energy produced when the sun is shining is hard to use; and
  - Energy consumed after the sun goes down is more problematic

- There are two dimensions to this mismatch: Diurnal and Seasonal
  - Energy storage is not difficult (but not cheap) on a diurnal basis
  - but storage more challenging on a seasonal basis
Diurnal Variation: the “Duck Curve”
This is the duck (net electricity loads in California vs. time of day)

Solar’s Surge
The proliferation of solar farms in California has led to an oversupply of power generation in the middle of the day and steep drop-off in the evening

Source: California ISO
California GHG Emissions Factors 2018

Hourly Emissions Factor (2030)

Energy efficiency remains essential to address annual variation

Potential Shift to Winter Peak Under High Electrification Scenario

NEEP: Northeastern Regional Assessment of Strategic Electrification, July 2017

https://neep.org/strategic-electrification-regional-assessment
Building Load Curve
Teaching the Duck to Fly”
But these methods are not recognized in Title 24 or RESNET 301

- They would require weighting energy use by an hourly “source multiplier”
- They would require algorithms for modeling user-controlled or grid-controlled actions to shift time of use
  - Running water heater only when factors are low
  - Charging and discharging batteries, both standalone and in cars
  - Slowing down air conditioner/heat pump when factors are high
  - Postponing appliance use, refrigerator defrost, etc., subject to user override
  - Dimming lights or turning them off automatically
Conclusions

• ZNE goal led to major improvements in residential Title 24
  – Even though the 2019 code is not all the way there, it is far stronger than it would have been otherwise

• The code should evolve toward Zero Emissions Buildings (ZEB)
  – When coupled with future changes to encourage electrification, Title 24 methods could accommodate time of use emissions factors to provide Zero Emissions
California Hourly Site-to-Source Energy Conversion Factors and GHG Emissions

Charles Kim, P.E.
Southern California Edison
2019 RESNET
Blue Pale Dot

• “… In our obscurity, in all this vastness, there is no hint that help will come from elsewhere to save us from ourselves.... To my mind, there is perhaps no better demonstration of the folly of human conceits than this distant image of our tiny world. To me, it underscores our responsibility to deal more kindly and compassionately with one another and to preserve and cherish that pale blue dot, the only home we’ve ever known.” --- Carl Sagan
How to Count for GHG from the Use of Energy?
Counting: $\Delta$ GHG emission / $\Delta$ Generation

- Non-Renewable Generators
  - EPA monitors emissions continuously
  - CA ISO records MW and MWh
    - Imports
    - Exports
    - Curtailment
How about from My Home?

• Data Source:
  • Electric Bill
  • Gas Bill

• How much GHG emissions from my energy use?
  • *Simply multiply by the EPA’s GHG emission factor to your energy usage?*

1. Non-Renewable Source
2. Heat Rate
3. Site

CO₂

T&D Loss CO₂

I see no GHG...
Does GHG emission rate change over a day?
GHG Emissions per Fuel Type

GHG Emissions per Fuel Type
Impacts of CA Renewable Portfolio Standard

[Source: California ISO]
Site Energy Needs from GHG Perspective
Determine/Estimate Site Energy Needs

How much energy does this building need?

Suppose these boxes represent hourly site energy needs by fuel types.

- Electricity
- RE and Non-RE
- Natural Gas (NG)
How to Separate Non-RE from RE?

GHG Emission Sources
How to Calculate “Non-RE” from Grid?

Multiply RE by *

* Grid Avg. Heat Rate
* 3412 Btu/kWh
* 0 Btu/kWh
Why not apply “Heat Rates” to Non-RE?
Can we correlate Electricity to GHG?
Presumption Valid? – Yes.

Which generators are we replacing when DMS occurs at a site?
Q1: What are we replacing with?
- Gen 1
- Gen 2
- Gen 3
- Gen N
- Marginal Gen

Q2: Which Perspective?
- Site
- Source
- TDV
- TDV+

Q2: Which Metric?
- Energy
- Economic
- GHG Emission
  - Avg. Grid GHG
  - SR Marginal
  - LR Marginal
How to give various credits to building designers/owners?

Site Need: 100 kWh

From the Grid:
- 60 kWh (Non-RE)
- 40 kWh (RE)

Site PV: 50 kWh (RE)

How to Credit the PV for Site Energy Need?

Choice:
- Credit Method 1
- Credit Method 2
Unintended Consequences?
Issues/Challenges/Opportunities

• Challenge: How should we account for energy efficiency, energy conservation, and renewable generation efforts at a site and reflect them at the generation source?
• How do we treat EE, Renewable Energy, and Bldg. Controls? Equally???
• Some measures/appliances can reduce more GHG than others; therefore, hourly schedules for building simulation become critical.
• WIP – Impacts on Building Simulation Results by new metrics...