DECARBONIZING EXISTING COMMERCIAL BUILDINGS

Webinar
6/24/20
DAVID ADLER
PROGRAM MANAGER
SAN DIEGO GREEN BUILDING COUNCIL

Photo by Daniel Guerra on Unsplash
SAN DIEGO GREEN BUILDING COUNCIL

MISSION
Inspire, educate and collaborate within our community to transform our built environment toward true sustainability

VISION
Our buildings and communities will regenerate and sustain the health and vitality of all life within a generation.
PARTNERSHIPS with LOCAL MUNICIPALITIES

- San Diego Regional Energy Partnership
- City of San Diego
- City of La Mesa
- City of Chula Vista
- City of El Cajon
- National City
- County of San Diego
2020 Focus

DECARBONIZATION  WATER REUSE  HEALTH & WELLNESS  EQUITY
Upcoming Events

San Diego Green Building Council hosts a variety of tours, workshops, and social events. Grow your network, maintain continuing education credits and get inspired at one of the upcoming gatherings:

**Upcoming events**

**JUNE 24**
**Decarbonizing Existing Commercial Buildings**
ONLINE WEBINAR
San Diego, CA
09:00 AM

**JUNE 26**
**SD LFC Materials Petal Webinar**
Zoom Webinar
12:00 PM
Presenter

Tony Sclafani, PE, CEM
Engineering Manager, Pacific Coast
Johnson Controls
Hello, my name
Decarbonizing Existing Commercial Buildings
Learning Objectives

1. Learn what decarbonization of buildings means.

2. Become familiar with practical applications of building system technologies to achieve decarbonization of existing commercial buildings.

3. Learn about the anticipated interactions between decarbonized buildings and other related topics of building performance such as electrification, demand response, gas and electric utilities, and other topics.
Conclusions

- Decarbonization of buildings means the elimination of carbon dioxide and other greenhouse gas emissions from buildings.
- Eliminating the use of natural gas in residential and commercial buildings would have the same impact as shutting off all power plants in California.
- Decarbonizing the building stock is a serious challenge.
- Energy transfer is dangerous.
- Use your judgment and professional experience to evaluate data and opinions.

Disclosure: My work is based on energy retrofits in existing commercial buildings.
Condensed Presentation
Background on Decarbonization
Definitions

- **Working definition**¹
  - Decarbonization is the process of reducing economy-wide carbon or other greenhouse gases.

- **“Deep Decarbonization”**
  - Reducing GHG emissions to achieve 2050 goals in the equivalent MMMTCO$_{2e}$.
  - In other words, when the goal is achieved we’ve successfully decarbonized.

- **Decarbonization of Buildings**
  - Elimination of carbon dioxide and other greenhouse gas emissions from buildings.

Source: California’s Building Decarbonization Opportunity: Knowing Where We Are and Delivering What We Need. Building Decarbonization Coalition.
Policy Progression

Energy Policy

Climate Policy
California Climate Goals

Statewide GHG Emissions

1990 Levels

2020  2030  2040  2045  2050
Methane

PATHWAY 2045
Update to the Clean Power and Electrification Pathway
November 2019

Buildings: Almost three-quarters of space and water heating needs to be electric by 2045. Given the long life cycles of space and water heating equipment, significant consumer awareness and education need to be supported now to speed adoption. Customers will benefit from the significant efficiency provided by electrification, as well as from energy efficiency and demand response programs that help to lower customer consumption and bills.
Methane (CH₄)

CH₄ has a global warming potential of 25, indicating one gram of CH₄ is equivalent to 25 grams of CO₂ over a 100-year timeframe. CH₄ is the second most important GHG in California, accounting for 9% of 2017 GHG emissions in CO₂ equivalent units.
Methane

Sources of CH₄ in California

Agriculture accounts for the majority of emissions, primarily from livestock enteric fermentation and manure management. Industrial sources and landfills are also important sources of CH₄. Other sources contribute only a small fraction to CH₄ emissions, and include residential, transportation, electricity generation, and commercial sources.

2017 Total CH₄ Emissions: 39.9 MMTCO₂e

- Oil & Gas Extraction: 16%
- Landfill: 21%
- Agriculture – Manure: 26%
- Agriculture – Enteric Fermentation: 28%
- Industrial – Other: 4%
- Other: 3%
- Agriculture – Other: 2%

Source: https://ww2.arb.ca.gov/ghg-descriptions-sources
Methane

- 2017 total California emissions ≈ 424.1MMTCO$_2$e
- Residential and commercial emissions ≈ 41.1MMTCO$_2$e (10%)
  - 38.6 MMTCO$_2$e from CO$_2$
    - 90% of the 41.1 is from combustion of natural gas
  - 1.4 MMTCO$_2$e from N$_2$O
  - 0.94 MMTCO$_2$e from CH$_4$

1. California’s Building Decarbonization Opportunity: Knowing Where We Are and Delivering What We Need. Building Decarbonization Coalition.
Methane

Is electrifying the heating systems in buildings a good value proposition?

\( \approx 10\% \) of total emissions in California is due to natural gas usage in residential and commercial buildings.

Compare with 9% of total emissions due to in-state electricity generation.

Eliminating the use of natural gas in residential and commercial buildings would have the same impact as shutting off all power plants in California.
Emissions by category

Commercial and Residential Fuel Combustion

Greenhouse gas emissions from the commercial and residential sectors are dominated by the combustion of natural gas and other fuels for household and commercial business use, such as space heating, cooking, and hot water or steam generation. Emissions from electricity use (e.g., air-conditioning, lighting, washer and dryer, refrigerator, etc.) is already accounted for in the Electric Power sector. Changes in annual fuel combustion emissions are primarily driven by variability in weather conditions and the need for heating in buildings, as well as population growth. In 2017, emissions increased slightly compared to 2016 due to a rise in residential natural gas use.

Emissions by category

≈25% of emissions come from buildings
Emissions within buildings

Is electrifying the heating systems in buildings an appropriate solution?

Source: https://www.c2es.org/document/decarbonizing-u-s-buildings/
Achieving Decarbonization
Design Approach

1. Establish the target
2. Maximize energy efficiency
3. Electrify
4. Implement renewables (PV)
Design Approach

- Efficiency reduces the cost of PV (via rightsizing)
- Reduced building loads and PV capacity mitigates the cost of electrical upgrades
Energy Uses in Buildings

- Electricity
  - Lighting
  - HVAC (ventilation and cooling)
  - Miscellaneous Loads
    - Plug loads
    - Refrigeration
    - Cooking
    - Process

- Natural Gas
  - HVAC (heating)
  - Domestic hot water (heating)
  - Process
LED Lighting

1. LED tubes
2. LED fixtures
3. LED fixtures with embedded controls
   1. Tuning
   2. Dimming
   3. Daylight harvesting
   4. Color changing
   5. Occupancy sensors
4. Networked
5. BAS-integrated
6. App enabled (asset tracking, wayfinding, etc.)
HVAC – Heating and Cooling Loads

- Reduce Envelope loads
  - Window film
  - Weatherization
  - Window replacement
  - Exterior EIFS insulation
  - Indoor furred insulation
  - Ceiling insulation
  - Roof insulation
  - Door adjustments, weatherization, replacement
HVAC – Heating and Cooling Loads

- Reduce* ventilation loads
  - Re-calculate outdoor air ventilation requirements based on actual building operation.
  - Perform testing, adjusting, and balancing to set correct minimum outdoor air flows. Make control system programming adjustments as needed.
  - Install or retro-commission economizer systems.
  - Make control system programming adjustments for outdoor air temperature lockout, unoccupied lockout, and optimal startup sequences of operation.

- *COVID-19
  - Follow ASHRAE guidance and maintain code compliance
HVAC - Equipment

- RTUs to heat pumps
- Packaged AHUs to electric heat
- Terminal unit replacement and conversion to WSHP or electric reheat
- Fan energy reductions
- Chillers (heat pump chillers, heat recovery chillers)
- Pumps
- Cooling towers
HVAC – Space Heating

- RTUs to heat pumps
- Packaged AHUs to electric heat
- Terminal unit replacement and conversion to WSHP or electric reheat
- Convert hot water boilers from gas to electric
- Steam systems
  - De-couple heating hot water (≈180F) from domestic hot water (≈120F)
  - Remove heat exchangers
  - Install electric boilers
Domestic Hot Water

- Heat Pump Hot Water Heaters
- Electric DHW heaters
  - Tankless
  - Storage tank
- Electric point-of-use hot water heaters
Miscellaneous Electrical Loads

- Plug load controls
- Refrigeration door seals, defrost controls, evaporator fan motor controls
- Consolidate and unplug unused refrigeration
- ENERGY STAR kitchen cooking and refrigeration equipment
- Kitchen exhaust hood controls
- Process equipment
  - Elevators
  - Air compressors
  - Shop equipment
Solar PV

- Carport PV
- Rooftop PV
- Ground mount PV
  - Fixed tilt
  - Single axis tracking
  - Dual axis tracking
Energy Storage

- Life cycle cost savings
- Time delay benefits
- Grid interaction benefits
- Value stacking and revenue generation
Controls

- Control of disparate building energy systems
- Integrations and APIs
- Optimization
User Interface

- Occupants’ proactive and ongoing role
- EG: COVID-19, PSPS, wildfires ("resiliency")
Electrical Load Reductions

1. LED lighting
2. Cooling system
3. Air distribution system
4. Reduction of miscellaneous loads
Electrical Load Additions

1. Electric vehicles
2. Space heating
3. Hot water heating
4. Process loads
The Boiler Situation

- Boiler electrification creates a large electrical load
- 1,000,000 Btu/hr input boiler provides ≈ 800,000 Btu/hr output
- 800,000 Btu/hr output ≈ 235 kW

- ≈$60k per electric boiler vs. $33k for gas
- + electrical upgrades ≈$10,000+++ 
- + solar capacity (sized relative to therm usage, not kW rating)
- + battery capacity
Electrical Distribution Upgrades

Distribution Panel
Electrical Distribution Upgrades

Service Entrance Switchboard
Learning Objectives

1. Learn what decarbonization of buildings means.

2. Become familiar with practical applications of building system technologies to achieve decarbonization of existing commercial buildings.

3. Learn about the anticipated interactions between decarbonized buildings and other related topics of building performance such as electrification, demand response, gas and electric utilities, and other topics.
Conclusions

- Decarbonization of buildings means the elimination of carbon dioxide and other greenhouse gas emissions from buildings.
- Eliminating the use of natural gas in residential and commercial buildings would have the same impact as shutting off all power plants in California.
- Decarbonizing the building stock is a serious challenge.
- Energy transfer is dangerous.
- Use your judgment and professional experience to evaluate data and opinions.

Disclosure: My work is based on energy retrofits in existing commercial buildings.
Background on Decarbonization
Google Trends | Explore

- decarbonization
  Search term.

United States  6/1/16 - 6/12/20  All categories  Web Search

Interest over time

Note

Jun 1, 2010  Jun 1, 2013  Jun 1, 2016  Jun 1, 2019
Definitions

- Working definition\(^1\)
  - Decarbonization is the process of reducing economy-wide carbon or other greenhouse gases.

- “Deep Decarbonization”
  - Reducing GHG emissions to achieve 2050 goals in the equivalent MMTCO\(_{2e}\).
  - In other words, when the goal is achieved we’ve successfully decarbonized.

- Decarbonization of Buildings
  - Elimination of carbon dioxide and other greenhouse gas emissions from buildings.

Source: California’s Building Decarbonization Opportunity: Knowing Where We Are and Delivering What We Need. Building Decarbonization Coalition.
Policy Progression

Energy Policy

Climate Policy
Policy Progression

  - In response to 1973 oil crisis. Goals included reducing energy demand and improving energy efficiency.
- 2005 – Kyoto Protocol enters into force
- 2015 – SB 350 Clean Energy and Pollution Reduction Act
- 2018 – SB 100 California Renewables Portfolio Standard Program: emissions of greenhouse gases
- 2018 – SB 1477 Low-emissions buildings and sources of heat energy
  - Led to CPUC rulemaking on building decarbonization (R.19-01-011).
California Climate Goals

- Executive Order S-3-05
  - By 2010, reduce GHG emissions to 2000 levels
  - By 2020, reduce GHG emissions to 1990 levels
  - By 2050, reduce GHG emissions to 80 percent below 1990 levels

- Executive Order B-30-15
  - By 2030, reduce GHG emissions to 40 percent below 1990 levels

- SB 100
  - 100% of all electricity must come from renewable and zero carbon sources by December 31, 2045.

- Executive Order B-55-18
  - By 2045, achieve carbon neutrality.

Targets total GHG emissions within the state of California

Fun Fact: SB 100 and EO B-55-18 were signed by Gov. Brown on the same day.
California Climate Goals

Statewide GHG Emissions

1990 Levels
What are greenhouse gases?

- “Gases that trap heat in the atmosphere are called greenhouse gases.” – US EPA
- Health and Safety Code 38505 identifies seven greenhouse gases that ARB is responsible to monitor and regulate in order to reduce emissions:
  1. Carbon dioxide (CO2)
  2. Methane (CH4)
  3. Nitrous oxide (N2O)
  4. Sulfur hexafluoride (SF6)
  5. Hydrofluorocarbons (HFCs)
  6. Perfluorocarbons (PFCs)
  7. Nitrogen trifluoride (NF3).
What are greenhouse gases?

92% of emissions come from CO₂ and CH₄
Methane

- Methane is converted into carbon dioxide after combustion
- 1 ton of methane (CH₄) emissions ≈ 25 to 35 tons of carbon dioxide emissions
- Natural gas is 70%-90% methane (and 0%-8% carbon dioxide)
- Gas leaks
  - ≈1.5% to 3% nationwide
Methane

Supply and Demand of Natural Gas in California

Natural gas continues to play an important and varied role in California. Nearly 45 percent of the natural gas burned in California was used for electricity generation, and much of the remainder consumed in the residential (21 percent), industrial (25 percent), and commercial (9 percent) sectors. California continues to depend upon out-of-state imports for nearly 90 percent of its natural gas supply, underscoring the importance of monitoring and evaluating ongoing market trends and outlook. Natural gas has become an increasingly important source of energy since the state’s power plants rely on this fuel.
Methane

- Natural gas leaks
  - >2% and no climate benefit
  - >3% and the climate change impact is doubled
  - ≈1.5% to 3% nationwide
  - Estimated at 3.6% (2.4% to 4.3%) for California

- Methane emissions are bad

Source: Presentation by Panama Bartholomy to Silicon Valley Clean Energy; https://www.youtube.com/watch?v=dRkz_FPi6z8&t=998s
Methane

Agriculture accounts for the majority of emissions, primarily from livestock enteric fermentation and manure management. Industrial sources and landfills are also important sources of CH₄. Other sources contribute only a small fraction to CH₄ emissions, and include residential, transportation, electricity generation, and commercial sources.

2017 Total CH₄ Emissions: 39.9 MMTCO₂e
### Methane

**California Methane Inventory for 2000-2017**

--- by Category as Defined in the 2008 Scoping Plan

#### million tonnes of CO₂ equivalent - (based upon IPCC Fourth Assessment Report’s 100-yr Global Warming Potentials)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>0.83</td>
<td>0.82</td>
<td>0.01</td>
<td>18.48</td>
<td>17.74</td>
<td>9.86</td>
<td>7.86</td>
<td>0.73</td>
<td>0.70</td>
<td>0.03</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>7.31</td>
<td>7.21</td>
<td>0.09</td>
<td>34.40</td>
</tr>
<tr>
<td>2001</td>
<td>0.84</td>
<td>0.83</td>
<td>0.01</td>
<td>18.74</td>
<td>17.99</td>
<td>9.76</td>
<td>8.23</td>
<td>0.75</td>
<td>0.73</td>
<td>0.02</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>7.46</td>
<td>7.31</td>
<td>0.10</td>
<td>34.80</td>
</tr>
<tr>
<td>2002</td>
<td>0.85</td>
<td>0.84</td>
<td>0.01</td>
<td>19.93</td>
<td>19.14</td>
<td>10.39</td>
<td>8.76</td>
<td>0.78</td>
<td>0.78</td>
<td>0.02</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>7.54</td>
<td>7.41</td>
<td>0.11</td>
<td>36.20</td>
</tr>
<tr>
<td>2003</td>
<td>0.86</td>
<td>0.85</td>
<td>0.01</td>
<td>20.37</td>
<td>19.54</td>
<td>10.47</td>
<td>8.66</td>
<td>0.85</td>
<td>0.85</td>
<td>0.02</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>7.72</td>
<td>7.59</td>
<td>0.10</td>
<td>36.64</td>
</tr>
<tr>
<td>2004</td>
<td>0.87</td>
<td>0.86</td>
<td>0.01</td>
<td>19.66</td>
<td>18.85</td>
<td>10.25</td>
<td>8.69</td>
<td>0.88</td>
<td>0.88</td>
<td>0.02</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>7.94</td>
<td>7.65</td>
<td>0.10</td>
<td>36.95</td>
</tr>
<tr>
<td>2005</td>
<td>0.87</td>
<td>0.87</td>
<td>0.01</td>
<td>20.32</td>
<td>18.93</td>
<td>10.00</td>
<td>9.13</td>
<td>0.77</td>
<td>0.77</td>
<td>0.02</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>7.67</td>
<td>7.71</td>
<td>0.10</td>
<td>37.64</td>
</tr>
<tr>
<td>2006</td>
<td>0.88</td>
<td>0.88</td>
<td>0.01</td>
<td>20.47</td>
<td>19.73</td>
<td>10.10</td>
<td>9.31</td>
<td>0.74</td>
<td>0.74</td>
<td>0.02</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>8.04</td>
<td>7.88</td>
<td>0.12</td>
<td>39.42</td>
</tr>
<tr>
<td>2007</td>
<td>0.89</td>
<td>0.89</td>
<td>0.01</td>
<td>22.93</td>
<td>21.97</td>
<td>10.00</td>
<td>9.13</td>
<td>0.71</td>
<td>0.71</td>
<td>0.02</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>8.19</td>
<td>8.02</td>
<td>0.13</td>
<td>39.45</td>
</tr>
<tr>
<td>2008</td>
<td>0.90</td>
<td>0.90</td>
<td>0.01</td>
<td>22.77</td>
<td>22.02</td>
<td>10.00</td>
<td>9.38</td>
<td>0.82</td>
<td>0.82</td>
<td>0.02</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>8.28</td>
<td>8.11</td>
<td>0.14</td>
<td>39.40</td>
</tr>
<tr>
<td>2009</td>
<td>0.91</td>
<td>0.91</td>
<td>0.01</td>
<td>22.18</td>
<td>21.35</td>
<td>10.00</td>
<td>9.38</td>
<td>0.84</td>
<td>0.84</td>
<td>0.02</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>8.38</td>
<td>8.19</td>
<td>0.15</td>
<td>39.80</td>
</tr>
<tr>
<td>2010</td>
<td>0.91</td>
<td>0.91</td>
<td>0.01</td>
<td>22.77</td>
<td>21.93</td>
<td>10.00</td>
<td>9.38</td>
<td>0.88</td>
<td>0.88</td>
<td>0.02</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>8.40</td>
<td>8.22</td>
<td>0.16</td>
<td>39.94</td>
</tr>
<tr>
<td>2011</td>
<td>0.91</td>
<td>0.91</td>
<td>0.01</td>
<td>22.87</td>
<td>21.78</td>
<td>10.00</td>
<td>9.38</td>
<td>0.86</td>
<td>0.86</td>
<td>0.02</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>8.43</td>
<td>8.28</td>
<td>0.17</td>
<td>39.86</td>
</tr>
<tr>
<td>2012</td>
<td>0.91</td>
<td>0.91</td>
<td>0.01</td>
<td>22.67</td>
<td>21.35</td>
<td>10.00</td>
<td>9.38</td>
<td>0.81</td>
<td>0.81</td>
<td>0.02</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>8.50</td>
<td>8.22</td>
<td>0.18</td>
<td>39.71</td>
</tr>
<tr>
<td>2013</td>
<td>0.91</td>
<td>0.91</td>
<td>0.01</td>
<td>22.31</td>
<td>21.44</td>
<td>10.00</td>
<td>9.38</td>
<td>0.89</td>
<td>0.89</td>
<td>0.02</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>8.63</td>
<td>8.40</td>
<td>0.19</td>
<td>39.94</td>
</tr>
<tr>
<td>2014</td>
<td>0.91</td>
<td>0.91</td>
<td>0.01</td>
<td>22.35</td>
<td>21.74</td>
<td>10.00</td>
<td>9.38</td>
<td>0.88</td>
<td>0.88</td>
<td>0.02</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>8.70</td>
<td>8.47</td>
<td>0.20</td>
<td>39.85</td>
</tr>
<tr>
<td>2015</td>
<td>0.91</td>
<td>0.91</td>
<td>0.01</td>
<td>22.58</td>
<td>21.18</td>
<td>10.00</td>
<td>9.38</td>
<td>0.85</td>
<td>0.85</td>
<td>0.02</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>8.80</td>
<td>8.64</td>
<td>0.21</td>
<td>39.31</td>
</tr>
<tr>
<td>2016</td>
<td>0.91</td>
<td>0.91</td>
<td>0.01</td>
<td>21.89</td>
<td>21.10</td>
<td>10.00</td>
<td>9.38</td>
<td>0.83</td>
<td>0.83</td>
<td>0.02</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>8.93</td>
<td>8.62</td>
<td>0.22</td>
<td>39.49</td>
</tr>
<tr>
<td>2017</td>
<td>0.91</td>
<td>0.91</td>
<td>0.01</td>
<td>22.03</td>
<td>21.10</td>
<td>10.00</td>
<td>9.38</td>
<td>0.82</td>
<td>0.82</td>
<td>0.02</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>8.78</td>
<td>8.60</td>
<td>0.23</td>
<td>39.49</td>
</tr>
</tbody>
</table>

Source: https://ww3.arb.ca.gov/cc/inventory/data/tables/ghg_inventory_scopingplan_2000-17ch4.pdf
# Methane

California Carbon Dioxide Inventory for 2000-2017 — by Category as Defined in the 2008 Scoping Plan

<table>
<thead>
<tr>
<th>million tonnes of CO₂ equivalent - (based upon IPCC Fourth Assessment Report's 100-yr Global Warming Potentials)</th>
</tr>
</thead>
<tbody>
<tr>
<td>--------</td>
</tr>
<tr>
<td><strong>Commercial and Residential</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td><strong>Residential Fuel Use</strong></td>
</tr>
<tr>
<td>Natural Gas</td>
</tr>
<tr>
<td>Other Fuels</td>
</tr>
<tr>
<td><strong>Fugitive Emissions</strong></td>
</tr>
<tr>
<td><strong>Commercial Fuel Use</strong></td>
</tr>
<tr>
<td>Other Fuels</td>
</tr>
<tr>
<td><strong>Commercial Cogeneration Heat Output</strong></td>
</tr>
<tr>
<td>Agriculture</td>
</tr>
<tr>
<td><strong>Crop Growing &amp; Harvesting</strong></td>
</tr>
<tr>
<td>Soil Preparation and Disturbances</td>
</tr>
<tr>
<td><strong>General Fuel Use</strong></td>
</tr>
<tr>
<td>Diesel</td>
</tr>
<tr>
<td>Natural Gas</td>
</tr>
<tr>
<td>Gasoline</td>
</tr>
<tr>
<td>Other Fuels</td>
</tr>
</tbody>
</table>

**Total CO₂ Emissions** | 412.44 | 427.00 | 424.61 | 423.98 | 432.43 | 423.83 | 419.73 | 424.63 | 420.76 | 391.42 | 380.54 | 374.94 | 381.11 | 377.35 | 373.00 | 369.90 | 356.81 | 350.96


Source: https://ww3.arb.ca.gov/cc/inventory/data/tables/ghg_inventory_scopingplan_2000-17ch4.pdf
A Third of California Methane Traced to a Few Super-Emitters

By Esprit Smith,
NASA’s Earth Science News Team

Views from NASA’s Methane Source Finder, a tool that provides methane data for the state of California. The data are derived from airborne remote-sensing, surface-monitoring networks and satellites and are presented on an interactive map alongside infrastructure information. Credit: NASA/JPL-Caltech

Larger view
Methane

Is electrifying the heating systems in buildings an appropriate solution?

PATHWAY 2045
Update to the Clean Power and Electrification Pathway
November 2019

Buildings: Almost three-quarters of space and water heating needs to be electric by 2045. Given the long life cycles of space and water heating equipment, significant consumer awareness and education need to be supported now to speed adoption. Customers will benefit from the significant efficiency provided by electrification, as well as from energy efficiency and demand response programs that help to lower customer consumption and bills.
Emissions by sector

26%-27% of emissions come from buildings
Emissions within buildings

**Figure 1:** Total CO₂ Emissions from the Commercial and Residential Sectors (2016)

- **Commercial**
  - Space Heating, Cooling, Ventilation: 30%
  - Cooking, Appliances, Electronics, Lighting: 32%
  - Water Heating: 4%
  - Other: 14%

- **Residential**
  - Space Heating and Cooling: 38%
  - Cooking, Appliances, Electronics, Lighting: 24%
  - Water Heating: 15%
  - Other: 23%

*Note: *Other in both the commercial and residential sector includes items such as data servers, medical imaging equipment, ceiling fans, and pool pumps which are categorized as "miscellaneous electric loads" by EIA.

A roadmap for rapid decarbonization

Johan Rockström, Owen Gaffney, Joeri Rogelj, Malte Meinshausen, Nebojsa Nakicenovic, Hans Joachim Schellnhuber

Science 24 Mar 2017
Vol. 355, Issue 6331, pp. 1269-1271
DOI: 10.1126/science.aah3443

2017–2020: No-Brainers

Annual emissions from fossil fuels must start falling by 2020. Well-proven (and ideally income-neutral) policy instruments such as carbon taxes, cap and trade systems, feed-in tariffs, and quota approaches can global political climates through an appropriate policy mix.

2020–2030: Herculean Efforts

Economies must implement the no-brainer mitigation measures plus the first wave of smart and disruptive action. Improving energy efficiency alone would reduce emissions 40 to 50% by around 2030 in many domestic and industrial cases (9).
Achieving Decarbonization
Design Approach

1. Establish the target
2. Maximize energy efficiency
3. Electrify
4. Implement renewables (PV)
Design Approach

- Efficiency reduces the cost of PV (via right-sizing)
- Reduced building loads and PV capacity mitigates the cost of electrical upgrades
Washington Leads to a Low Carbon Future

Pathways to 2050
How Washington can reduce our greenhouse gas pollution by 80%

Three Pillars to Achieve Results

1. Investing in Energy Efficiency
   
2. Increasing Low Carbon Electricity
   
3. Electrifying the Economy

- Throughout the economy saves money and increases energy self-sufficiency.
- Reduces our use of fossil fuels and builds on Washington's legacy of clean power.
- Reduces emissions from buildings, vehicles, and processes.
What are we designing to offset?

- Site vs. source?
- National averages?
- Real-time values?
- TDV emissions?
- Commute?
- Water?
- Embodied carbon?
“Embodied Carbon”

Fabricating the materials that comprise buildings—like concrete, steel, and windows—also releases a significant amount of carbon into the atmosphere. These emissions are called “embodied carbon” because the carbon emissions from producing and transporting materials have already occurred prior to construction and are fixed. Therefore, this amount of carbon emissions are symbolically represented (embodied) by the building itself.
“Embodied Carbon”

What is embodied carbon?

“Cradle to gate”

Carbon Lifecycle of Building

Source: https://www.imt.org/should-i-stay-or-should-i-go-the-embodied-carbon-of-new-and-existing-buildings/
Energy Uses in Buildings

- Electricity
  - Lighting
  - HVAC
  - Miscellaneous Loads
    - Plug loads
    - Refrigeration
    - Cooking
    - Process

- Natural Gas
  - HVAC (heating)
  - Domestic hot water (heating)
  - Process
“Deep Energy Retrofits”

- Holistic approach vs. isolated systems
- Occupants’ proactive and ongoing role
- Contrast with “Deep Decarbonization”
LED Lighting

1. LED tubes
2. LED fixtures
3. LED fixtures with embedded controls
   1. Tuning
   2. Dimming
   3. Daylight harvesting
   4. Color changing
   5. Occupancy sensors
4. Networked
5. BAS-integrated
6. App enabled (asset tracking, wayfinding, etc.)
LED Lighting

- Every fixture can be an IP addressable
- Unlimited zoning
- Maximized savings
- Data
HVAC – Heating and Cooling Loads

- Reduce Envelope loads
  - Window film
  - Weatherization
  - Window replacement
  - Exterior EIFS insulation
  - Indoor furred insulation
  - Ceiling insulation
  - Roof insulation
  - Door adjustments, weatherization, replacement
HVAC – Heating and Cooling Loads

- Reduce* ventilation loads
  - Re-calculate outdoor air ventilation requirements based on actual building operation.
  - Perform testing, adjusting, and balancing to set correct minimum outdoor air flows. Make control system programming adjustments as needed.
  - Install or retro-commission economizer systems.
  - Make control system programming adjustments for outdoor air temperature lockout, unoccupied lockout, and optimal startup sequences of operation.

- *COVID-19
  - Follow ASHRAE guidance
HVAC - Equipment

- RTUs to heat pumps
- Packaged AHUs to electric heat
- Terminal unit replacement and conversion to WSHP or electric reheat
- Fan energy reductions
- Chillers (heat pump chillers, heat recovery chillers)
- Pumps
- Cooling towers
HVAC – Space Heating

- RTUs to heat pumps
- Packaged AHUs to electric heat
- Terminal unit replacement and conversion to WSHP or electric reheat
- Convert hot water boilers from gas to electric
- Steam systems
  - De-couple heating hot water (≈180°F) from domestic hot water (≈120°F)
  - Remove heat exchangers
  - Install electric boilers
Domestic Hot Water

- Heat Pump Hot Water Heaters
- Electric DHW heaters
  - Tankless
  - Storage tank
- Electric point-of-use hot water heaters
Miscellaneous Electrical Loads

- Plug load controls
- Refrigeration door seals, defrost controls, evaporator fan motor controls
- Consolidate and unplug unused refrigeration
- ENERGY STAR kitchen cooking and refrigeration equipment
- Kitchen exhaust hood controls
- Process equipment
  - Elevators
  - Air compressors
  - Shop equipment
Solar PV

- Carport PV
- Rooftop PV
- Ground mount PV
  - Fixed tilt
  - Single axis tracking
  - Dual axis tracking
Energy Storage

- Life cycle cost savings
- Time delay benefits
- Grid interaction benefits
- Value stacking and revenue generation
Controls

- Control of disparate building energy systems
- Integrations and APIs
- Optimization
User Interface

- Recall “deep retrofits”
- Occupants’ proactive and ongoing role
- EG: COVID-19, PSPS, wildfires (“resiliency”)
Practical Considerations
Electrical Load Reductions

- LED lighting
- Cooling system
- Air distribution system
- Reduction of miscellaneous loads
Electrical Load Additions

- Electric vehicles
- Space heating
- Hot water heating
- Process loads
The Boiler Situation

- Boiler electrification creates a large electrical load
- 1,000,000 Btu/hr input boiler provides ≈ 800,000 Btu/hr output
- 800,000 Btu/hr output ≈ 235 kW

- ≈$60k per electric boiler vs. $33k for gas
- + electrical upgrades ≈$10,000+++  
- + solar capacity (sized relative to therm usage, not kW rating)
- + battery capacity
Electrical Distribution Upgrades

Distribution Panel
Electrical Distribution Upgrades

Service Entrance Switchboard
Electrical Distribution Upgrades

Utility Distribution Transformer
Electrical Distribution Upgrades

Utility Distribution Transformer
Electrical Distribution Upgrades

Utility Distribution Transformer
Electrical Distribution Upgrades

Electrical Substation
# Electrical Distribution Upgrades

<table>
<thead>
<tr>
<th>Upgrade Type</th>
<th>Location</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>New panels</td>
<td>Behind the meter</td>
<td>Manageable</td>
</tr>
<tr>
<td>New service entrance switchboard</td>
<td>Behind the meter</td>
<td>Expensive</td>
</tr>
<tr>
<td>New utility distribution transformer</td>
<td>In front of the meter</td>
<td>Very expensive</td>
</tr>
<tr>
<td>Substation improvements</td>
<td>In front of the meter</td>
<td>Worst case</td>
</tr>
</tbody>
</table>
EV Load Additions

≈ 30 Amps per Level 2 charger

Think malls, stadiums, campuses, etc.
Solar PV and Energy Storage

- Do it once? Switchboard upgrades
- Flexibility = value
Zero Net Energy (ZNE)

What about ZNE?

ZNE building - An energy-efficient building where, on a source energy basis, the actual annual consumed energy is less than or equal to the on-site renewable generated energy.

Focus is shifting from energy to climate (from what to why).
Measurement & Verification

“Measurement and Verification” (M&V) is the process of using measurement to reliably determine actual savings created within an individual facility by an energy management program.
Water

Emissions are associated with water treatment and distribution.

Similar to embodied carbon.
Delivery Methods

Design-Bid-Build
Design-Build
Construction Manager at Risk (aka CM/GC)
Construction Management Multi-Prime
Public Private Partnership (P3)
Integrated Project Delivery

Consider the benefits of holistic, integrated, design and responsibility for performance outcomes.
Project Finance

- Grants, rebates, incentives
- Capital projects
- Lease purchase
- Bond financing
- Third party ownership

Involve financial stakeholders early
AC vs. DC

- Solar PV generates DC power
- EV chargers provide DC power
- DC microgrids under study

AC for the foreseeable future. Buildings are wired for AC.
Digital Transformation

- Building Systems
  - Standalone legacy systems
- Smart Systems
  - Optimization and analytics
- Interconnected Systems
  - EG: HVAC + lighting
- Converged Systems
  - Shared technology stack, interoperable sensors
- AI & Data Driven Systems
  - Event-based, personalized, shares data across enterprise

In the near future “apps” for buildings will be common.
Demand Response

• Per Title 24:

• DEMAND RESPONSE is short-term changes in electricity usage by end-use customers from their normal consumption patterns. Demand response may be in response to:
  • a. changes in the price of electricity; or
  • b. participation in programs or services designed to modify electricity use
    • i. in response to wholesale market prices or
    • ii. when system reliability is jeopardized.

• DEMAND RESPONSE SIGNAL is a signal sent by the local utility, Independent System Operator (ISO), or designated curtailment service provider or aggregator, to a customer, indicating a price or a request to modify electricity consumption, for a limited time period.

• DEMAND RESPONSIVE CONTROL is a kind of control that is capable of receiving and automatically responding to a demand response signal.

In 2020, people benefit from artificial intelligence every day: music recommender systems, Google maps, Uber, and many more applications are powered with AI. However, the confusion between the terms artificial intelligence, machine learning, and deep learning remains. One of popular Google search requests goes as follows: “are artificial intelligence and
AI Insights from the Harvard Business Review

What AI will add to the global economy:
- $13T

Believe a Smart-Building strategy will become a competitive differentiator:
- 46%

AI will help fill skills gaps with 50% of facility managers set to retire in the next 5-10 years:
- 50%

Are you ready?
Only 8% of companies are ready for the impact AI will have on their business.*

Funding the right spaces in the right places
"Smart buildings can enhance the occupant experience and how we create a better place for our employees by getting them more connected, active, and productive."

Enhanced leadership
Automating the data-driven aspects of leadership enables managers to focus on people and drive strategy.*

Public Health

Source: https://www.cdc.gov/climateandhealth/effects/default.htm
Climate Equity

- Energy poverty
- Price volatility
- Limited ability to mitigate climate risks (EG: electrification)
Jobs

Residential + Commercial Building Characteristics and Gas Use

- Equipment Manufacturing
- Renewable Energy Construction
- Electricity Generation and Distribution
- Building Electrification
- Gas Distribution

Increase in Direct Employment by Sector
Decrease in Direct Employment by Sector
Job Quality
Worker Retention and Transition

Recommendations

Safety

Risk of wildfires vs. risk of natural gas explosions. Energy in any form can cause injury.
Natural Gas Utilities

- Resource adequacy role
- Natural gas is better for environment than coal
Electric Utilities

- Traditional utilities (SDGE)
- New developments (CCAs)
- Solution to the PV re-sizing problem may be to balance electrical purchases. SDGE EcoChoice and EcoShare.
- Utility-to-building communications and control
Learning Objectives

1. Learn what decarbonization of buildings means.

2. Become familiar with practical applications of building system technologies to achieve decarbonization of existing commercial buildings.

3. Learn about the anticipated interactions between decarbonized buildings and other related topics of building performance such as electrification, demand response, gas and electric utilities, and other topics.
Conclusions

- Decarbonization of buildings means the elimination of carbon dioxide and other greenhouse gas emissions from buildings.
- Eliminating the use of natural gas in residential and commercial buildings would have the same impact as shutting off all power plants in California.
- Decarbonizing the building stock is a serious challenge.
- Energy transfer is dangerous.
- Use your judgment and professional experience to evaluate data and opinions.
Resources

CARB
https://ww2.arb.ca.gov/our-work/programs/ghg-inventory-program

The Building Decarbonization Coalition
http://www.buildingdecarb.org/

CPUC
https://www.cpuc.ca.gov/BuildingDecarb/

Icons made by Freepik from www.flaticon.com
End of Presentation