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Docket Number:	21-IEPR-06
Project Title:	Building Decarbonization and Energy Efficiency
TN #:	239134
Document Title:	Presentation - An Evaluation of the Potential for Deep Decarbonization in the Industrial Sector by 2050
Description:	S1.1B Elizabeth Dutrow, U.S. Environmental Protection Agency
Filer:	Raquel Kravitz
Organization:	US EPA
Submitter Role:	Public
Submission Date:	8/2/2021 11:08:28 AM
Docketed Date:	8/2/2021

An Evaluation of the Potential for Deep Decarbonization in the Industrial Sector by 2050

Elizabeth Dutrow
US Environmental Protection Agency
Climate Protection Partnerships Division



Who we are – ***ENERGY STAR Industrial Partnership***

- ENERGY STAR promotes energy efficiency and decarbonization in the industrial sector through its work with 32 industries & more than 800 corporations
- We provide tools that engage specific sectors in greater energy efficiency
 - *Plant energy performance indicators* – benchmarking tools score energy performance for a plant within its industry nationwide
 - *Energy guides* – actual opportunities within a sector for reducing energy consumption and GHGs
 - *Focus industries* – companies in a sector convene to share best practices and support tool development
 - *Certification of plants* - top quartile energy performance for plants in the sector
 - *Goal setting tools* - include Challenge for Industry, plant assessment (treasure hunts), campaigns, etc.
 - *Network of energy managers*

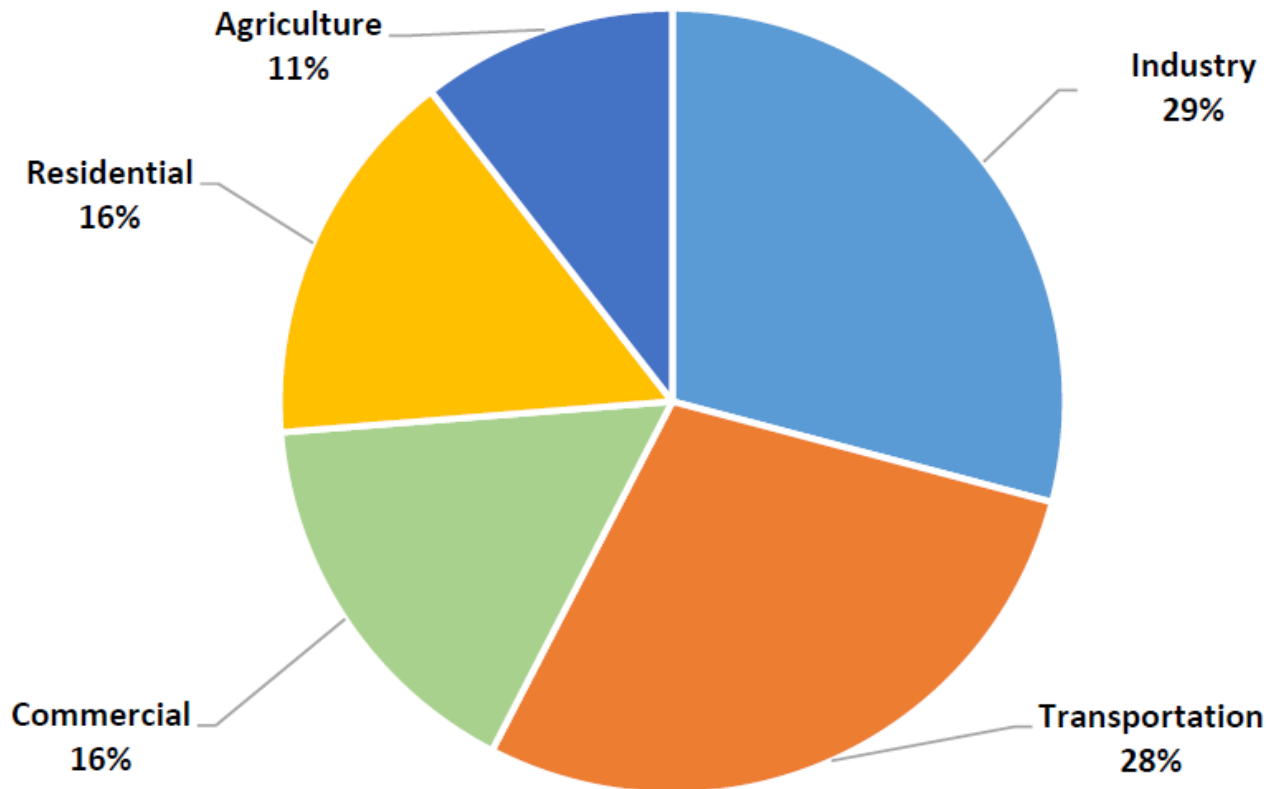


Evaluation co-authors

- **Gale Boyd, *associate research professor* in the Social Science Research Institute and Department of Economics at Duke University**
- **Ernst Worrell, *professor of energy, resources and technological change* in the Copernicus Institute at Utrecht University**
- **Josh Smith, *director of public policy* at ICF**
- **Elizabeth Dutrow, *physical scientist and lead for the ENERGY STAR Industrial Partnership, Climate Protection Partnerships Division, US EPA***



Why consider the industrial sector?



2018 US GHG emissions by economic sector,
electricity emissions allocated to sectors, US EPA 2020



Why this evaluation

- **Many have studied manufacturing sector opportunities**
 - **Some explore specific technologies**
 - **Others examine options for specific sectors**
 - **All show potential is there for industrial decarbonization**
 - **Question: what is the full impact when considering opportunities for increased energy efficiency, electrification, renewables and grid balancing?**
- **How much decarbonization is feasible?**



Scope of the evaluation

- **Manufacturing sector (NAICS 31-33)**
- **Consider opportunities for energy-related emissions reductions**
- **Assess how the manufacturing sector can contribute to deep energy/emissions reductions by 2050, examining the pillars of:**
 - 1. Energy Efficiency**
 - 2. Electrification**
 - 3. Renewables**
 - 4. Grid Balancing**

***Additional consideration was given to hydrogen, CHP, CCUS, and circular economy.**
- **Baseline: Energy Information Administration's Annual Energy Outlook**



Industry subsectors evaluated

- **Iron & steel**
- **Cement**
- **Chemicals**
- **Pulp & paper**
- **Petroleum refining**
- **Aluminum & glass**
- **“Light” industry**



Example: zero-carbon paper industry

Energy Efficiency

- Large technical potential

Material Efficiency

- Changing demand patterns
- Increased recycling

Renewable Energy

- Industry based on renewable resource
- Deep geothermal

New Process Designs

- Pulping – Biotechnology
- Papermaking – Water-free papermaking

Electrification

- New drying technologies (microwave)



Example: zero-carbon cement industry

- **Energy Efficiency**
 - Sustain ongoing improvements
- **Material Efficiency**
 - Increase blending
 - Improve design & concrete recycling
- **Renewables**
 - Increase use of alternative fuels
 - Onsite renewables
- **Carbon Capture & Storage**
 - Under study
- **New Processes/Raw Materials**
 - Potential TBD



Estimated potential across the sectors

DDM Opportunity	Bulk Chemicals	Cement, Lime	Light Industry	Oil Refining	Pulp & Paper	Steel	Aluminum, Glass
Energy Efficiency	Medium	High	High	High	High	High	High
Material Efficiency	Medium	Medium	Medium	Medium	High	High	Medium
Industry-Specific: Renewables	Medium	Medium-high	High	Low	High	Low	n/a
Industry-Specific: Hydrogen	Medium	Low	Low	Medium	Low	Medium	n/a
Industry-Specific: CCS	Medium	Medium	Low	Low-medium	Low	Medium	n/a
Grid Interaction: Electrification	Medium	Low	High	Low-medium	Medium	High	High
Grid Interaction: Balancing	Low	Medium	Medium	Low	Medium	Low	Medium
Total Reduction from Reference Case	76%	90%	95%	93%	100%	93%	97%



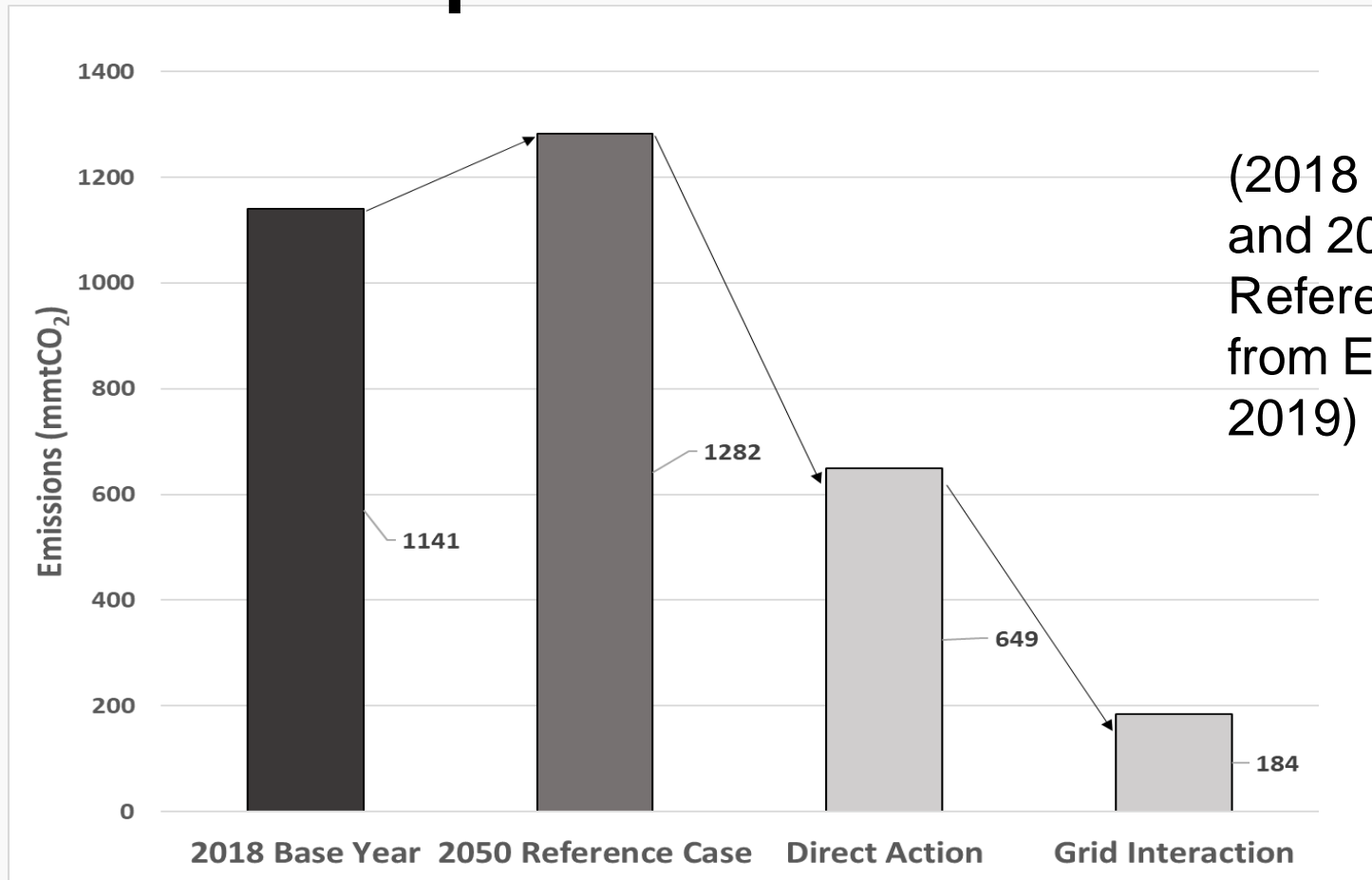
86 percent

the estimated reduction in CO₂ emissions feasible from the US manufacturing sector by 2050,

through the actions of *Energy Efficiency, Material Efficiency, Industry-Specific Technologies, and Power Grid Synergies*

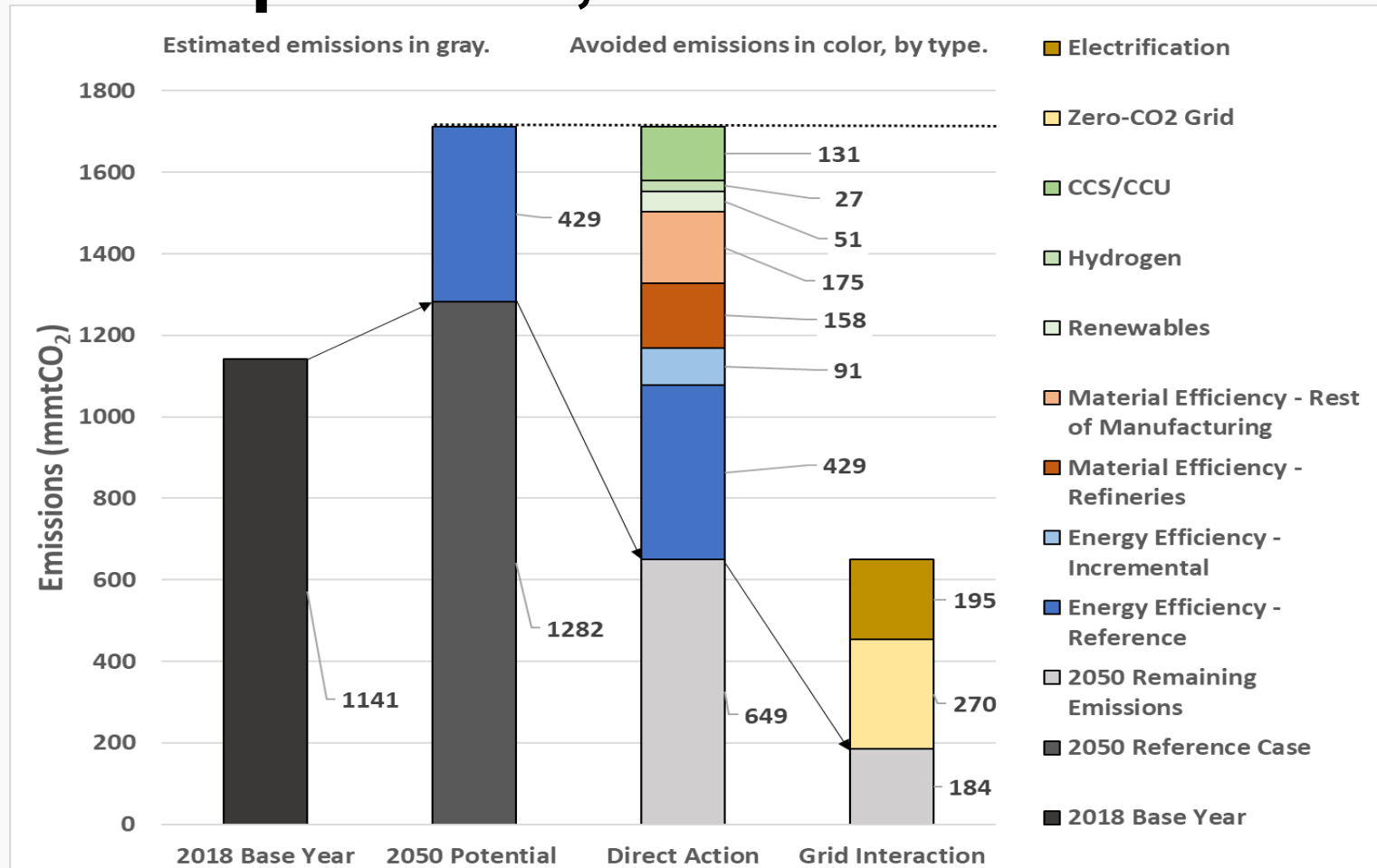


Reduction potential





Overall potential, detailed





Insights

- **Energy efficiency enables greater reductions**
 - **Has great potential remaining and is a key action for the early years & beyond**
 - **“Buys down” price of capital investments**
 - **Low in cost, relative to other options**
 - **Prevalent in all sectors**
 - **½ additional potential in heavy industry**
 - **½ additional potential in light industry**
 - **Some sectors have twice the benefit – by combining EE & electrification (e.g., heat pump)**



More insights

- **Material efficiency: changes in consumer demand are important to mitigate CO₂ emissions**
- **Decarbonized grid is key to enabling industrial electrification & green H₂ fuel production**
- **Electrification: short to mid-term, low temp processes in light industry promising; long-term some energy intensive sectors**
- **Renewable energy & grid decarbonization**
 - **Industry can play the role of enabler with VPPAs**
- **CCS for select industries with fewer decarbonization options**
- **H₂ has a role in certain industries**



Evaluation conclusions

- **Industry can reduce CO₂ emissions significantly**
 - **86% is estimated to be feasible**
- **One approach is unlikely to be successful for all sectors**
 - **Multiplicity of approaches (“all of the above”) is needed; more likely to be robust for industry, the economy, and the environment**
- **Start now, or the impact to industry will be significantly more costly in the future**
- **Follow manufacturing’s natural capital stock investment cycle**
 - **Least expensive approach: take advantage of full 30-year time horizon to naturally replace energy-using plants and equipment with more efficient and lower emissions technologies**



Carbon Intensity Benchmarks

- **Carbon metrics can inform and help industry in decision making.**
- **Plant level data on carbon emissions and production could provide a basis for calculating performance-based measures of carbon intensity.**
- **Carbon intensity benchmarks could assist industry in decarbonization planning and corporate financial climate risk assessment and disclosure.**