CO_2 Reduction with Calcined Clays and Alternative Fuels

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CO_2 Reduction with Calcined Clays and Alt. Fuels

- Calcined Clays and Pozzolans
  - PCA Roadmap
  - Past and Present
  - Future Opportunities
- Alternative Fuels
  - PCA Roadmap
  - Present Alternative Fuels Approaches
  - Hydrogen

The Future?

- PCA Roadmap for Carbon Neutrality calls for increasing substitution of cementitious materials
  - Pozzolans, flyashes, slags, calcined clays
  - Type IP, IT, etc.

PRODUCTION: AT THE CEMENT PLANT	
Replace raw materials with decarbonated materials	Using decarbonated materials eliminates CO_2 emissions from processing traditional raw materials, like limestone.
Use alternative fuels	Replacing traditional fossil fuels with biomass and waste-derived fuels lowers greenhouse gas (GHG) emissions and keeps materials out of landfills.
Continue efficiency improvements	Increasing energy efficiency reduces the amount of CO_2 emitted for each ton of product.
Implement carbon capture, utilization, and storage (CCUS) technology	CCUS directly avoids a significant portion of cement manufacturing emissions.
Promote new cement mixes	Creating new cements using existing and even alternative materials reduces emissions from mining for new materials, while optimizing the amount of clinker used ensures emissions correspond to necessary production.
Increase use of portland-limestone cement (PLC)	As an existing lower-carbon blend, universal acceptance of PLC will reduce clinker consumption and decrease emissions.

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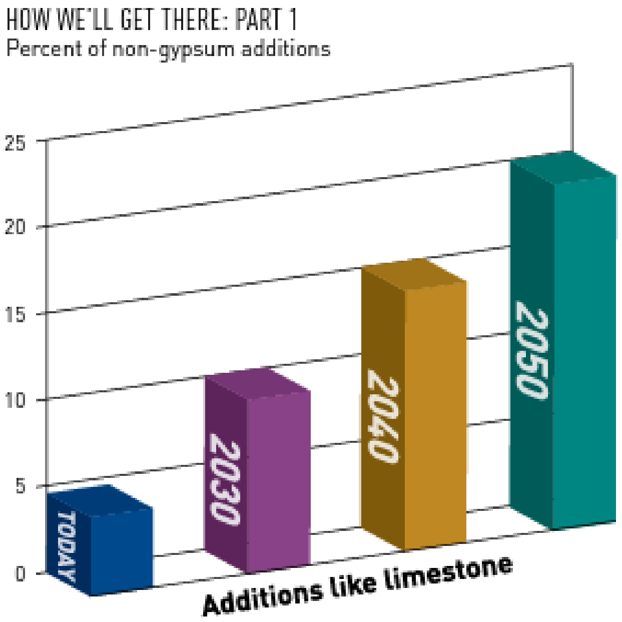
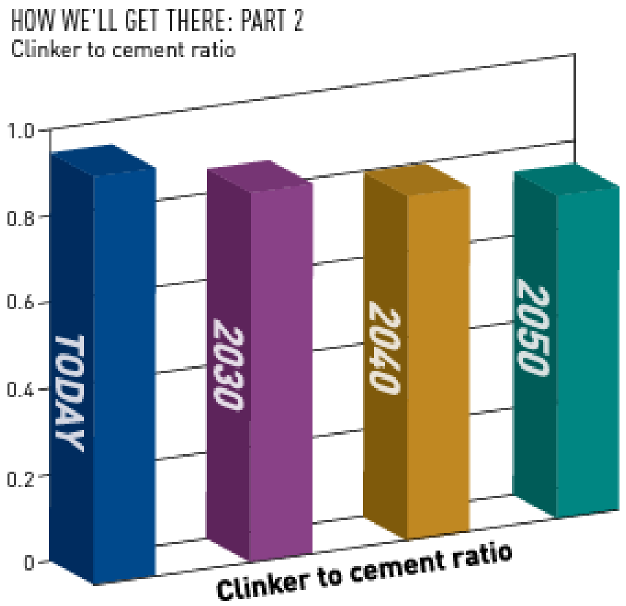
Optimizing cement: Changing the composition





Currently, cements have a clinker to cement ratio of more than 90%. The remaining material, gypsum, limestone, and processing additions can be partially replaced with supplementary cementitious materials (SCMs), which directly reduces the CO_2 that comes with clinker production – dropping the clinker amount 15% reduces the amount of CO_2 by 15%. SCMs include slag, fly ash, and silica fume. In many cases, these are industrial byproducts that would otherwise be landfilled and forgotten. Proper amounts of SCMs can improve durability and address the harmful chemical reactions caused by some aggregates.

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Pozzolan and Calcined Clay History

- Smeaton lighthouse mortar (1756) used 50:50 blend of hydraulic lime and pozzolana. Published in 1791.
- 19th Century – Numerous studies on pozzolans and calcined clays

- 1909 – Mixture of ground burnt clay and Portland cement sold as C.J. Potter’s Red Cement
- 1930’s – Studies of use of fly ash in cement as an artificial pozzolana
- 1940’s – Use of burnt clay and Portland Cement as an economic measure
- 1960’s – Extensive use of calcined clay in dam construction in Brazil

Bottom line – calcined clays and pozzolanas are not new technologies

The Future?

- Calcined clays
  - Lower energy than clinker production
    - Lower temperature for activation
    - Lower heat of reaction (i.e. less energy per ton of material calcined)
      - Moisture has a big impact

  - No $CaCO_3$ in feed means lower process emissions of CO_2
    - At least 50% lower CO_2 emission due to lack of CO_2 from calcination of material

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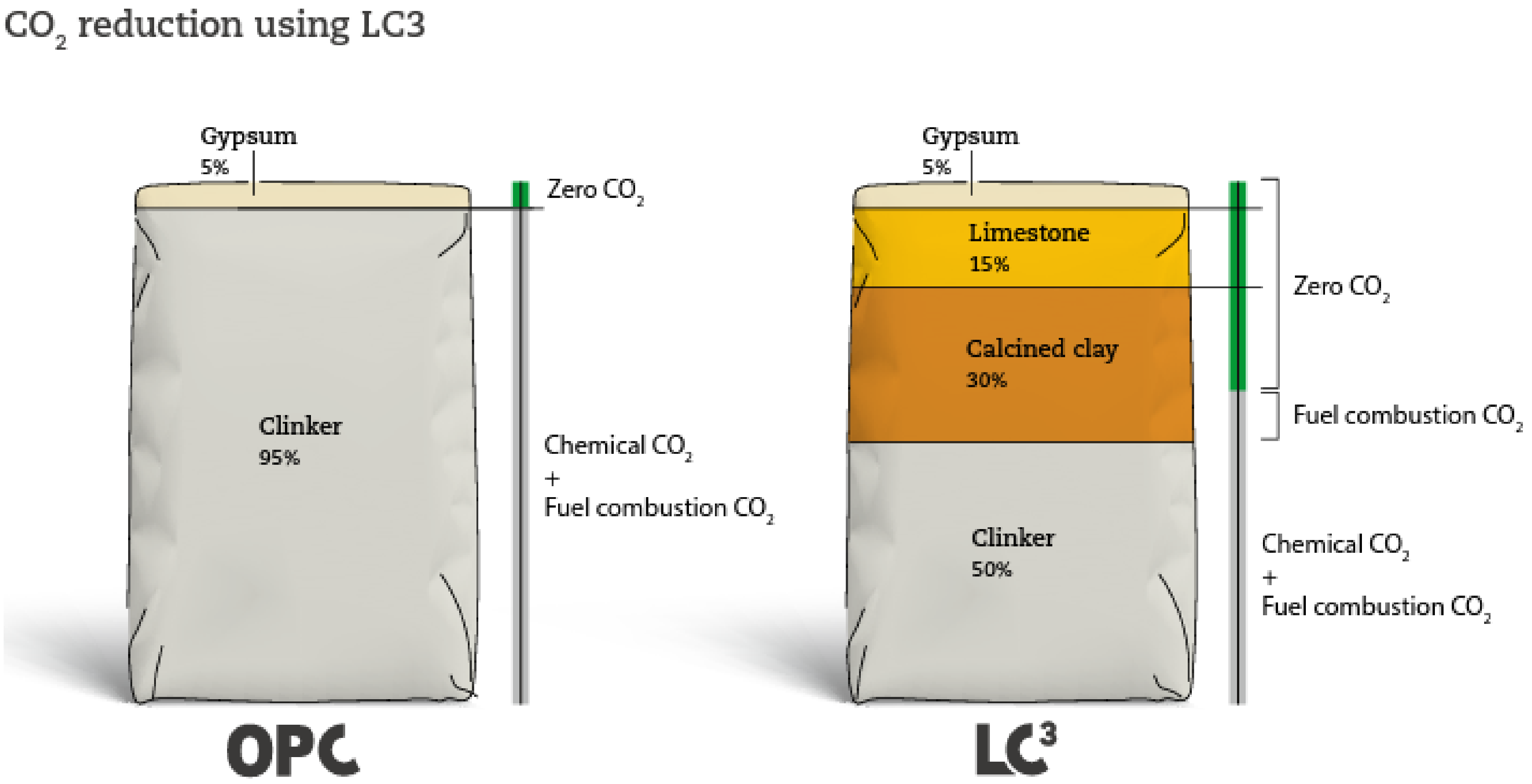
Example of Current Efforts

- LC3 – Limestone Calcined Clay Cement



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Tailings Ponds – Quarry ops

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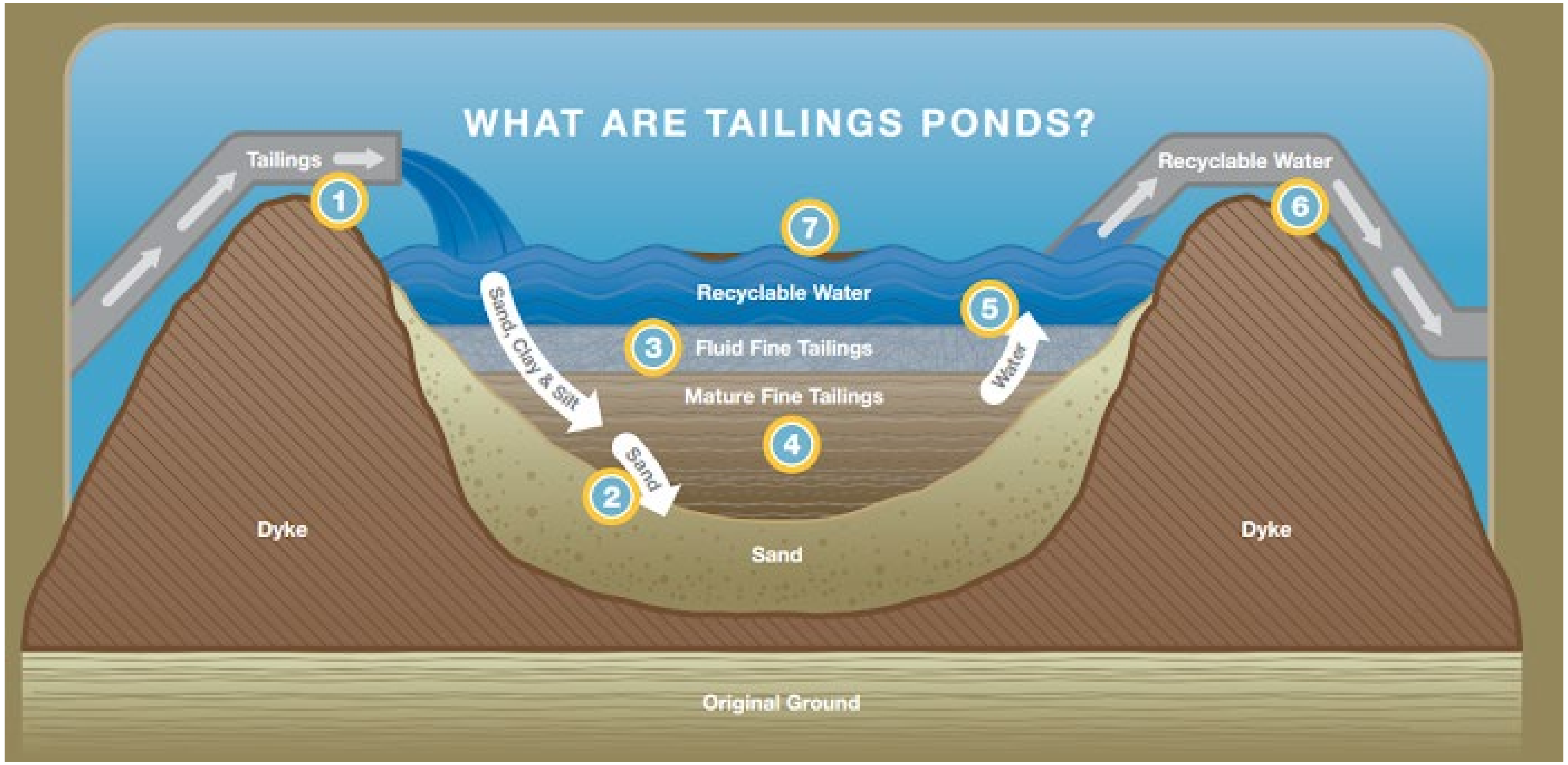
Tailings from Oil/Nat Gas Processing



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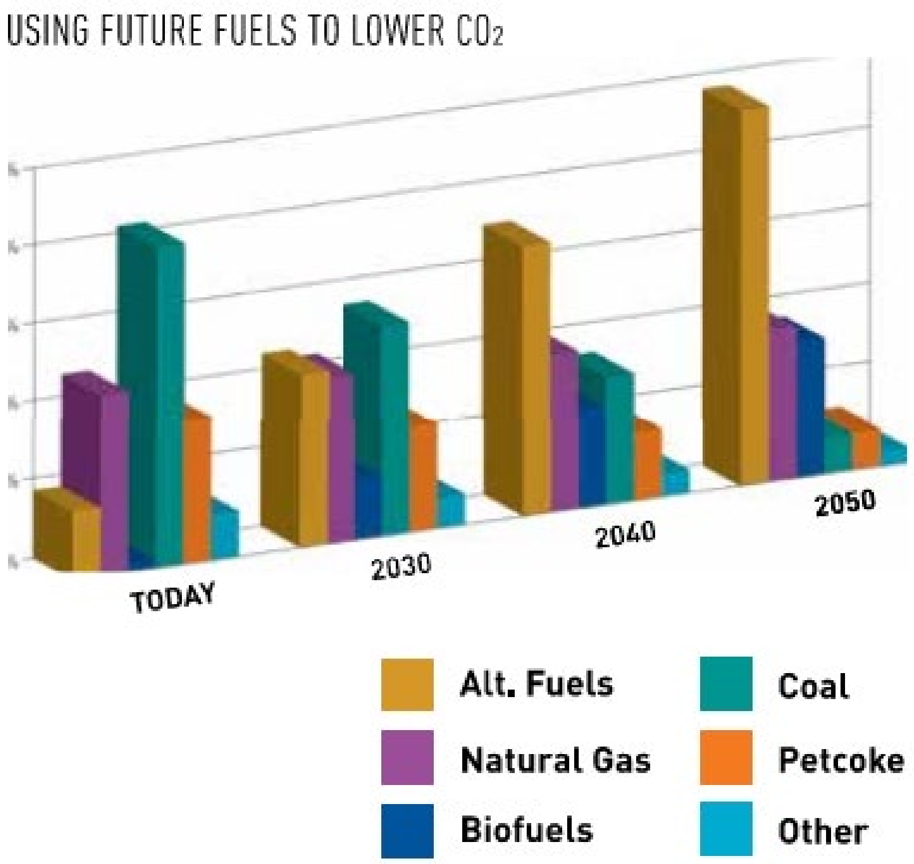
Alternative Fuels and CO_2 Reduction

Today the industry's fuel mix includes 60% coal and petcoke, and the industry wants to cut that amount by a factor of 5 with a goal of no more than 10% coal and petcoke use in 2050.

Cement plants are already equipped to use alternative fuel materials, provided the supply is available. With the right policies and regulations, alternative fuels could make up 50% of the industry's fuel mix.



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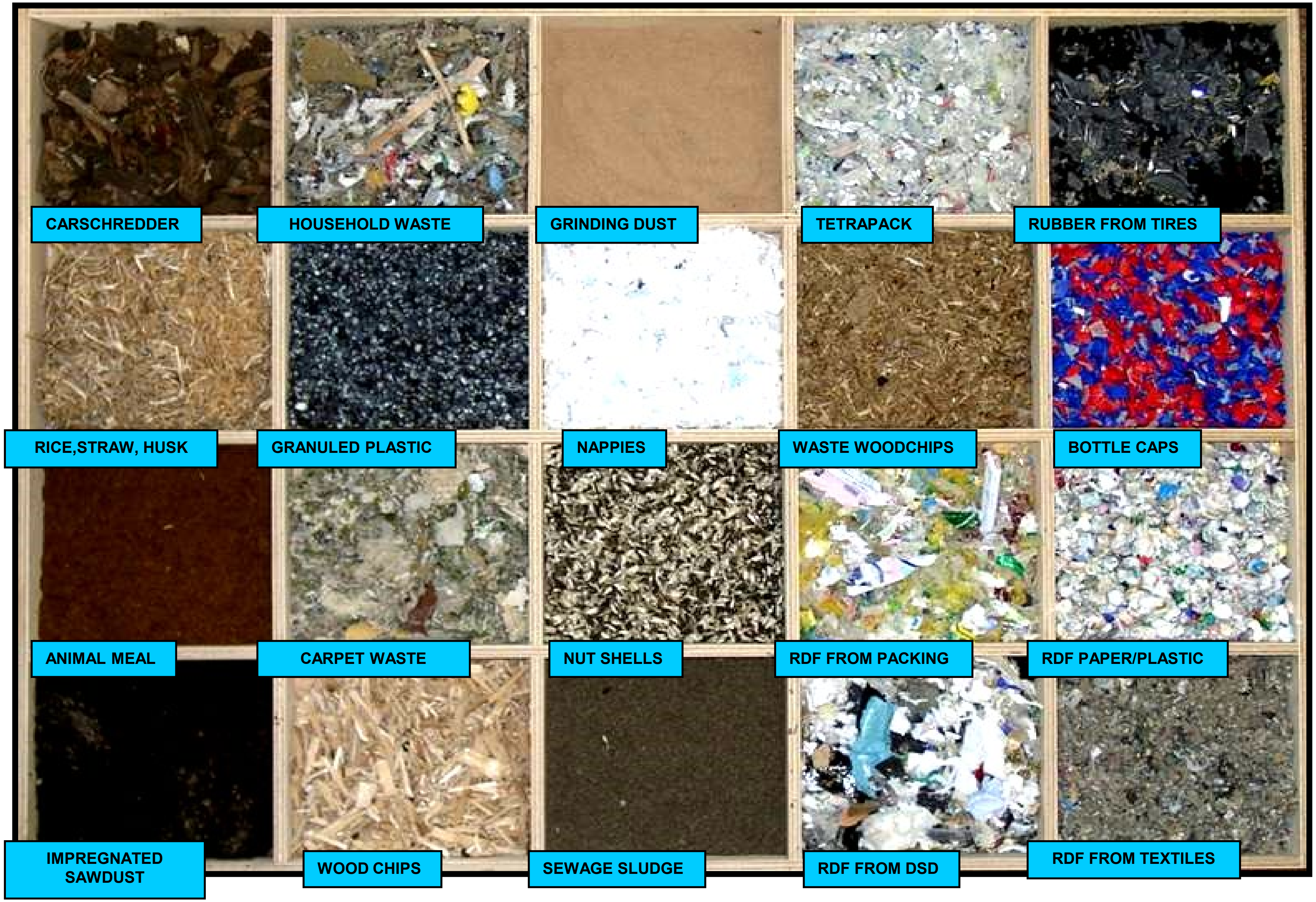

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Hydrogen

How can CO_2 be reduced or avoided at the clinker stage?

The CO_2 generated from combustion can be reduced through the transition from traditional fossil fuels like coal, petcoke, and natural gas to alternative fuels including biomass, secondary materials, and renewable energy sources and also from increased fuel efficiency in the manufacturing process. PCA also anticipates that hydrogen and other transformative fuels and transformative technologies will play a role. The CO_2 generated from the chemical reaction or chemical fact of life can be reduced by incorporating decarbonated raw materials, including slag and fly ash, as feedstocks. These are materials that have already been processed and no longer contain CO_2. Additionally, increasing the use of recycled materials diverts these materials from landfills.

Thermal Efficiency

- In theory, hydrogen firing can improve kiln thermal efficiency (lower partial pressure of CO_2 in the system)
- VDZ targets 13% improvement in thermal efficiency and a 10% usage of hydrogen in the fuel mix

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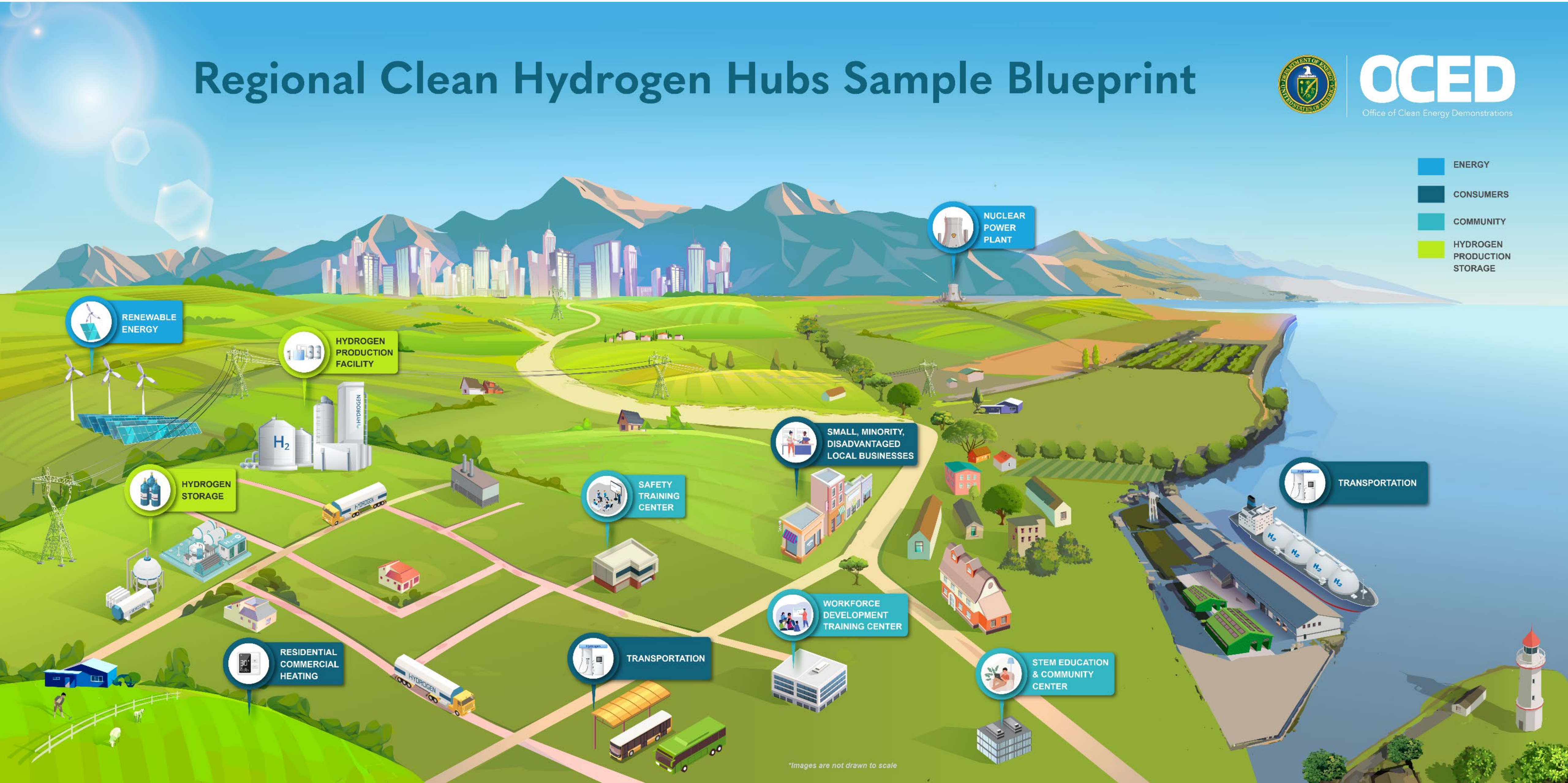
Regional Clean Hydrogen Hubs Sample Blueprint
OCED
Office of Clean Energy Demonstrations
ENERGY
CONSUMERS
COMMUNITY
HYDROGEN PRODUCTION STORAGE
NUCLEAR POWER PLANT
RENEWABLE ENERGY
HYDROGEN PRODUCTION FACILITY
HYDROGEN STORAGE
SAFETY TRAINING CENTER
SMALL, MINORITY, DISADVANTAGED LOCAL BUSINESSES
TRANSPORTATION
WORKFORCE DEVELOPMENT TRAINING CENTER
RESIDENTIAL COMMERCIAL HEATING
TRANSPORTATION
STEM EDUCATION & COMMUNITY CENTER
*Images are not drawn to scale

Hydrogen in Kiln Systems

- Tarmac – Tunstead (lime kiln trial)
- Chilean reference (lime kiln – 48% subst.)
- Chinese references (7 rotary lime kilns – COG/LDG* firing with 30% H_2 substitution)
- Chinese alumina plant (2 rotary lime kilns – COG firing with 55-60% H_2 substitution)

- Hanson – Ribbesdale (cement kiln trial)
- Cemex – San Pedro De Macoris (cement kiln trial)
- Argos – Piedras Azules (cement kiln trial)
- Cemex – Rudersdorf (planned 2025 industrial trial)
- ~20 announced small scale electroloysis systems
- 4 announced H2 projects by Cemex in Mexico

* - Coke Oven Gas / LD Gas

Technical Challenges

- Lime calcination is akin to boiling water, clinker production is akin to baking a cake
- Thermal profile of the kiln is critical
  - Hydrogen burns faster, with lower emissivity

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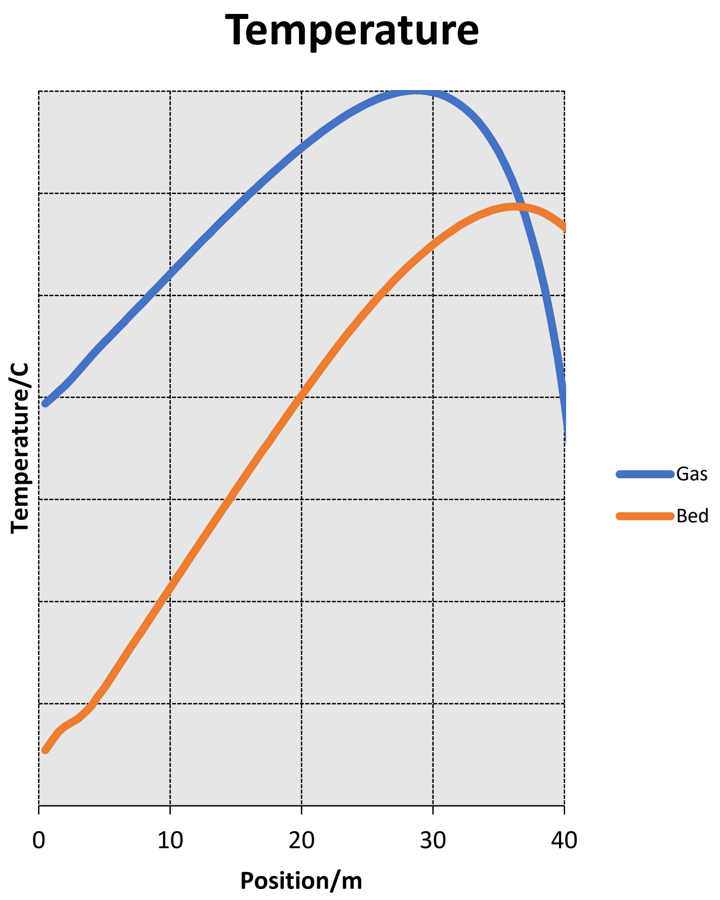
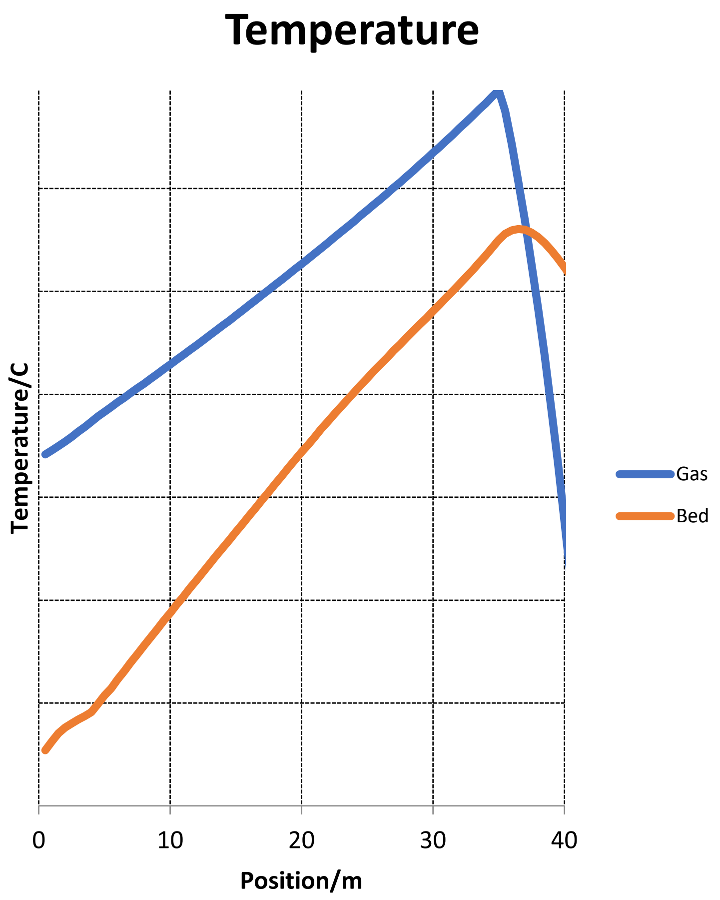
Kiln Temperature Profile





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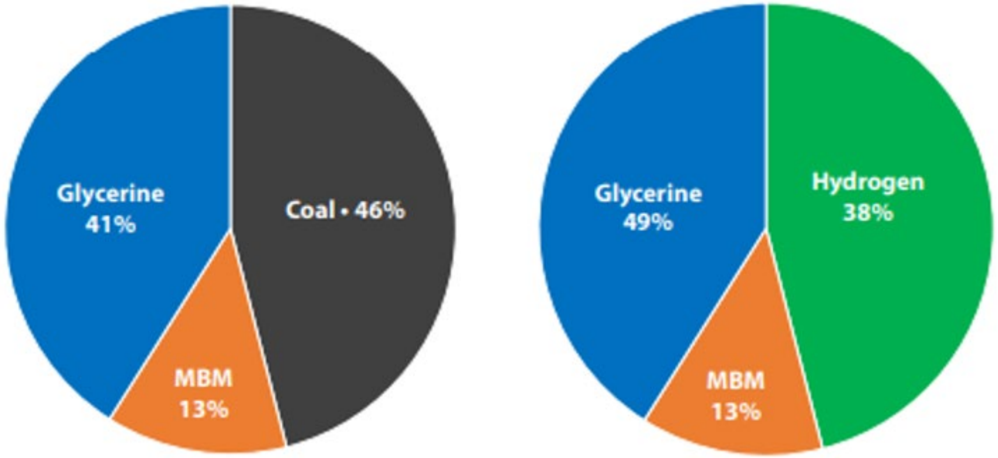
Technical Challenges

- Lime calcination is akin to boiling water, clinker production is akin to baking a cake
- Thermal profile of the kiln is critical
  - Hydrogen burns faster, with lower emissivity
- Burner adjustments and limitations



Left - Figure 1: Baseline fuel mix (left) and trial fuel mix (right) used during the Fuel Switching Project.

- Wet exhaust gases and dewpoint issues

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Questions?