Commercial-Scale Coal Gasification: Lessons Learned and R&D Needs

NATIONAL ENERGY TECHNOLOGY LABORATORY

GASIFICATION SYSTEMS

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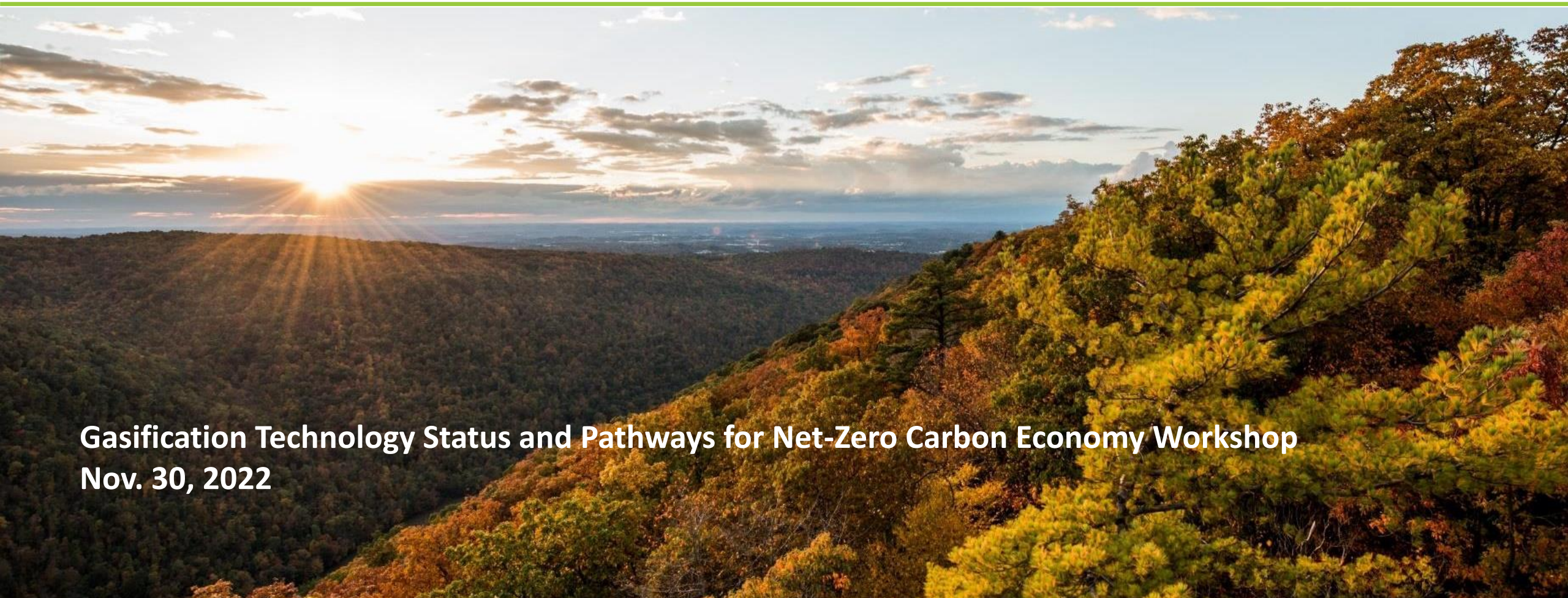
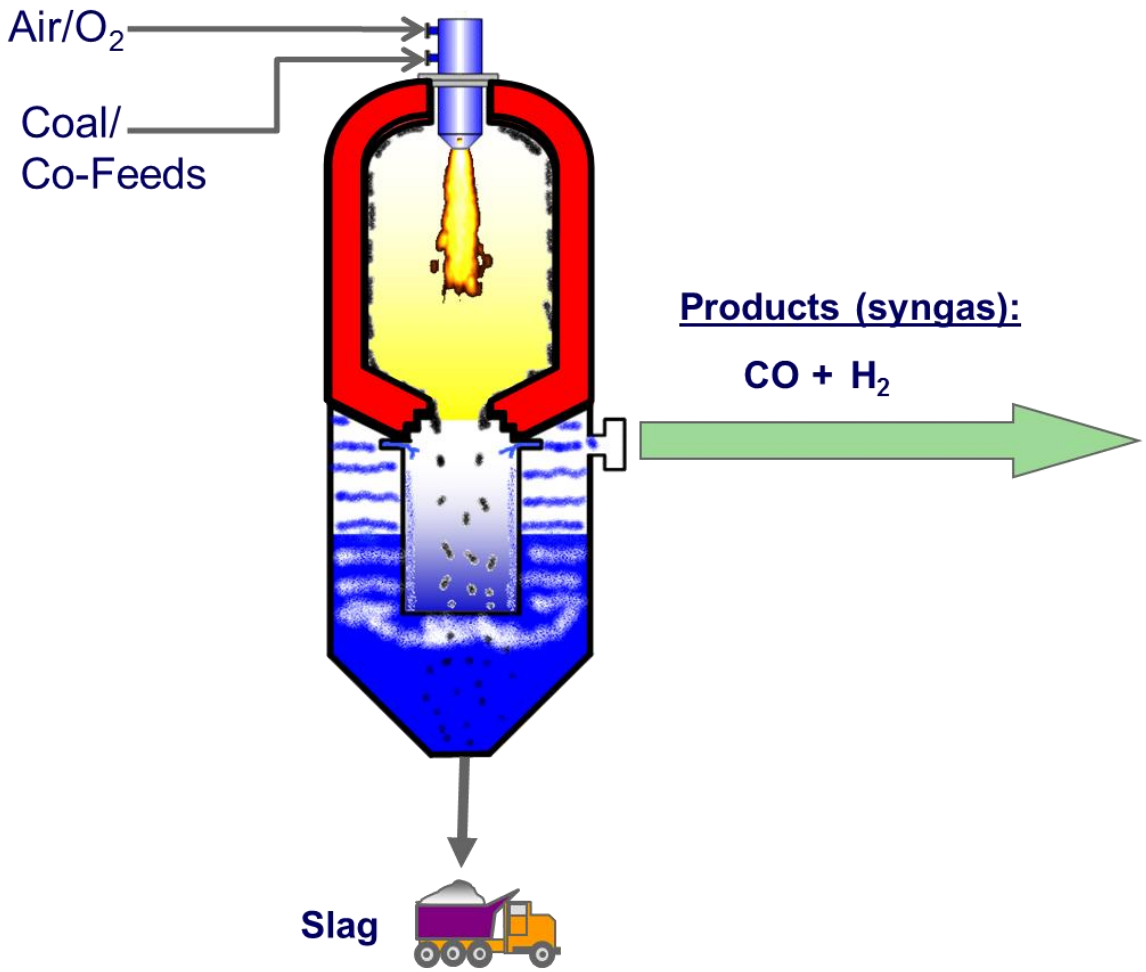


Gasification Technology Status and Pathways for Net-Zero Carbon Economy Workshop
Nov. 30, 2022

Outline

- Commercial Coal Gasification.
  - Current status.
  - New developments.
- Lessons Learned.
  - Learnings from success.
  - Learnings from adversity.
  - Key learnings summary.
- R&D Needs.

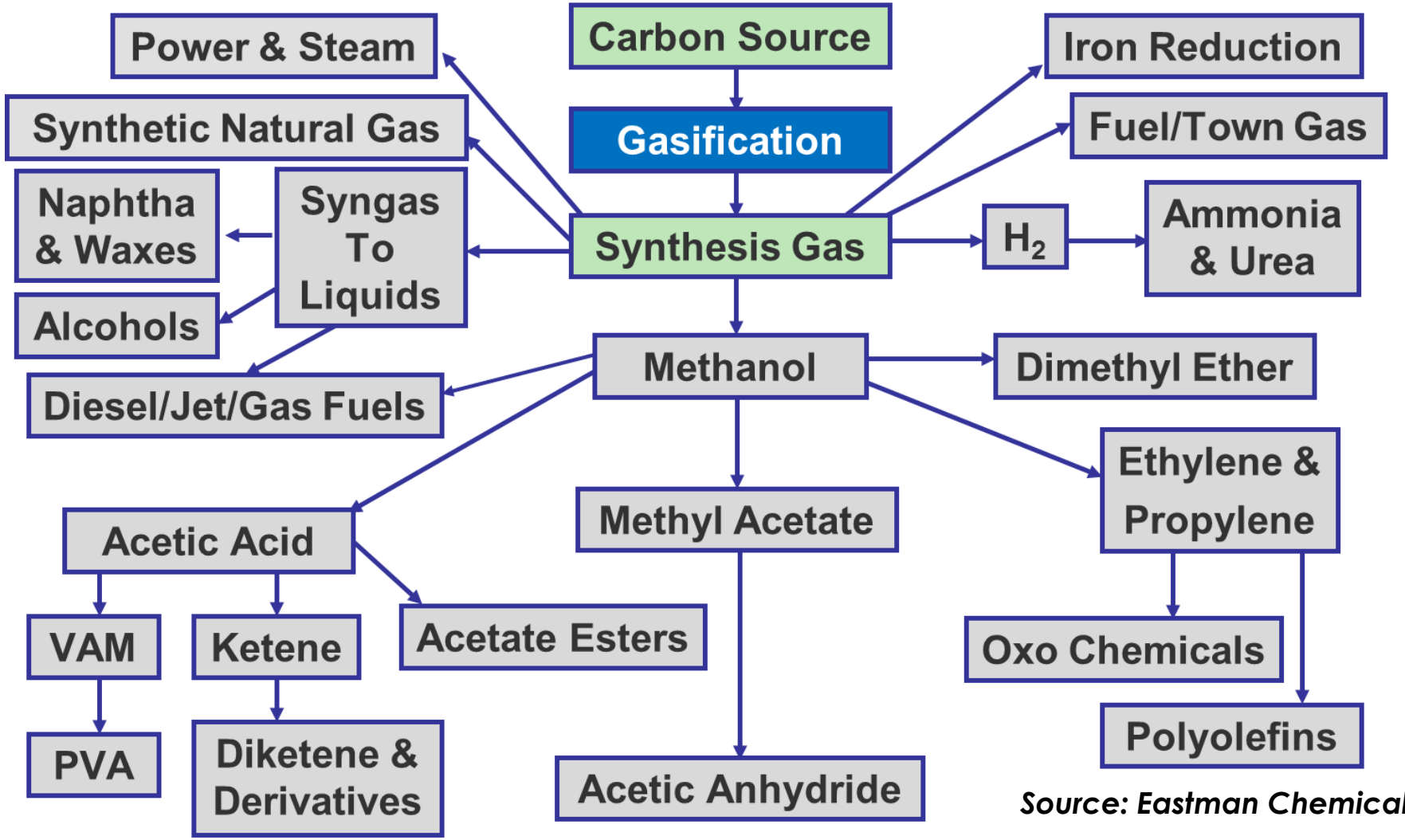


Commercial Coal Gasification Status

- Well-established technology.
- Decades of commercial deployment.
- 675 gasification sites in operation or under construction worldwide in 2019—1500 total gasifiers (excluding spares).*
- Major feedstocks: coal and/or petcoke.
- Great majority of these gasification projects have been successful!
- Location of gasification projects:
  - >70% in China.
  - 5–10% in India/Japan/other Asia.
  - ~10% in Africa/Middle East.
  - ~4% each in the U.S. and Europe.

**Annual gasification database survey conducted by the Global Syngas Technologies Council*

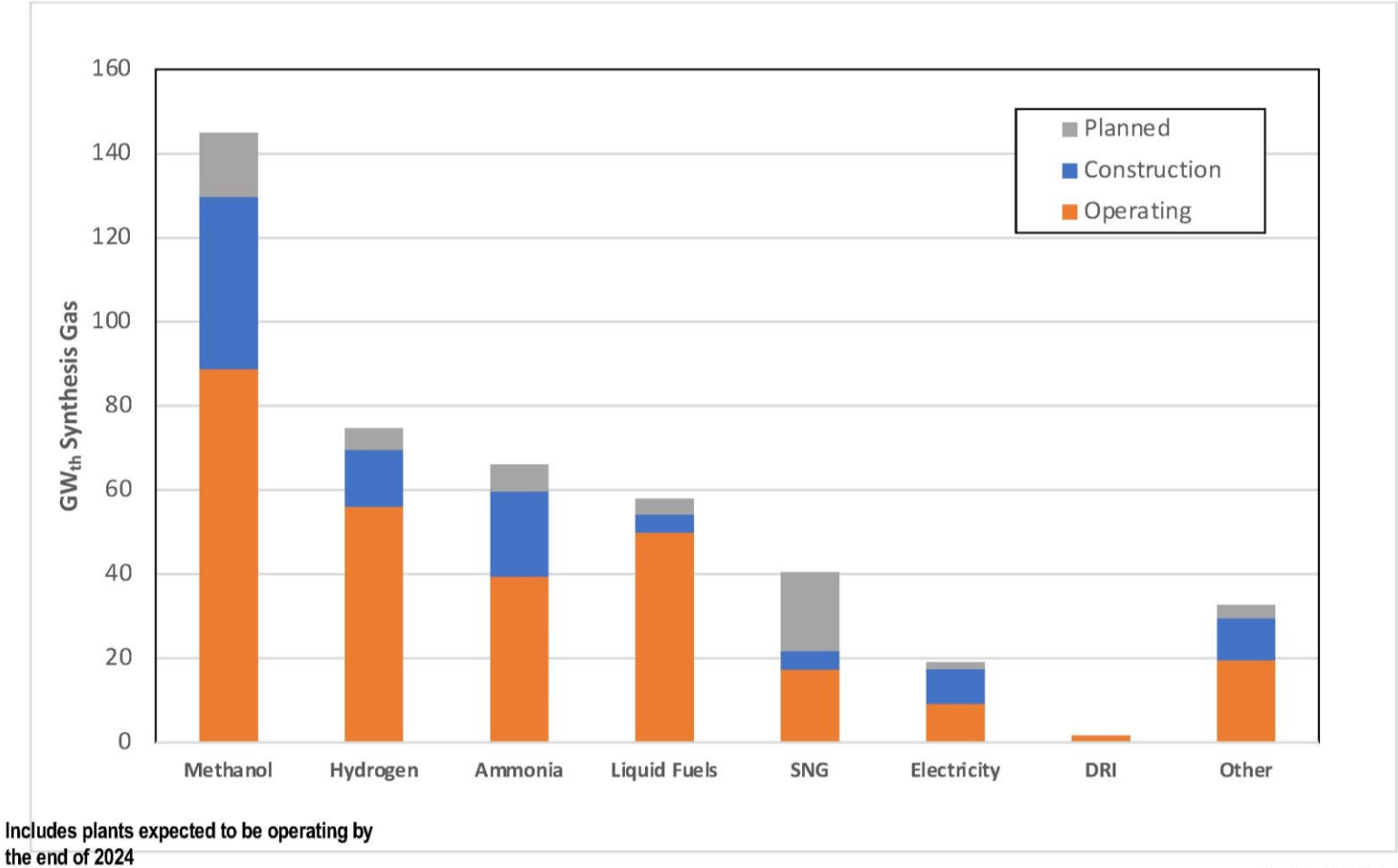
Gasification Can Produce Most Products Typically Made From Oil or Natural Gas



Source: Eastman Chemical Company

Most Gasification Projects Produce High-Value Products

Market Size and Growth - Gasification by Product

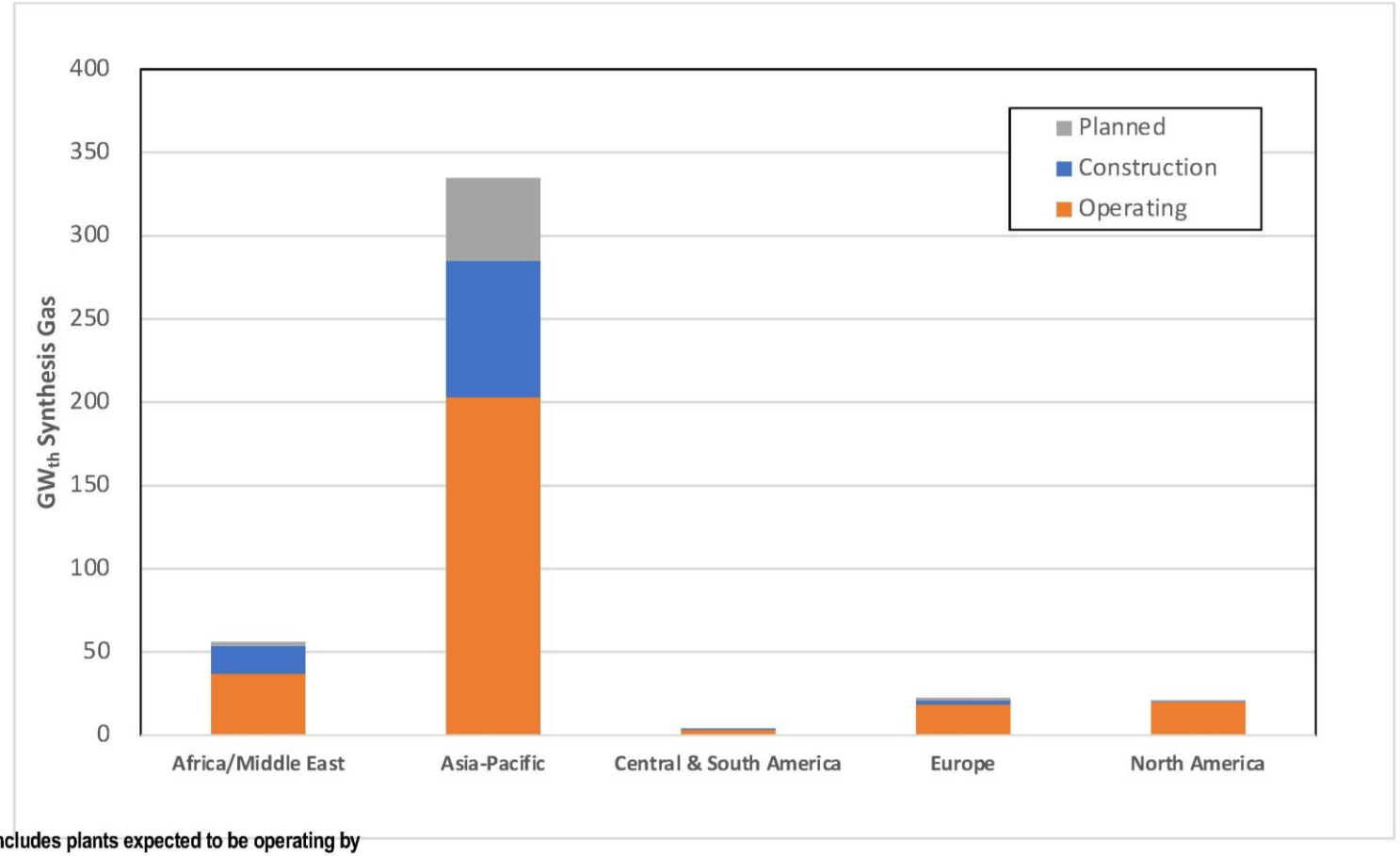


Includes plants expected to be operating by the end of 2024

Source: GSTC Database, 2021

Great Majority of Gasification Projects Are Located in the Asia-Pacific Region

Market Size and Growth - Gasification by Region

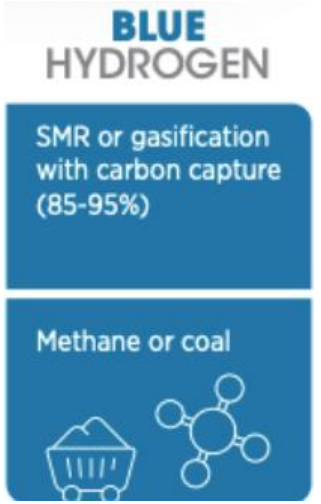


Includes plants expected to be operating by the end of 2024

Source: GSTC Database, 2021

New Developments

- New gasification vendors/designs/projects have been introduced in recent years.
  - Growing percentage based on biomass or waste feedstocks, sometimes as cofeeds with each other and/or with coal.
  - Green/blue hydrogen is increasingly a desired end-product.
- Methanol-to-olefins (via coal gasification) is still a major emphasis in the China market.
- The Russia-Ukraine conflict has generated some near-term increased interest in coal and other alternatives to natural gas, particularly for those regions dependent upon Russia for their energy.



Lessons Learned – Learnings From Success

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- Most successful coal/petcoke gasification projects: high-value products such as chemicals/fertilizers/fuels/hydrogen.
  - Gasifier designs that are simpler/standardized/more easily replicated.
  - Utilize multiple gasifiers with spares (only main gasifier block needs to be spared).
  - Operation at high availability/reliability is required to support continuous downstream operations: high motivation to succeed.
  - Located at large integrated sites with complementary support infrastructure and strong site-based technical knowhow and support.
  - Owners often willing to accept more risk as part of EPC contracts, thus lowering CAPEX.
  - Examples:
    - U.S. – Eastman Chemical Company, Coffeyville Resources.
    - Global – Sasol, Ube, multiple China-based locations.

Lessons Learned – Success Factors

- Successful gasification projects invest in:
  - Proactive troubleshooting.
  - Continual process improvement.
  - Preventative maintenance.
  - Result: causes of shutdowns and troublesome operations are addressed and eliminated over time.
- Government/university support/incentives and shared knowledge (e.g., China, Sasol).
- Utilization of specialized highly-trained staff (e.g., material scientists, process control and analytical experts, dedicated refractory masons, process improvement engineers).
- Most important success factor: sense of urgency and high-level commitment (focus, resources, staffing) to making the project a success!

Lessons Learned – Learnings from Adversity (1)

➢Problematic coal/petcoke gasification projects.

- Many of them designed as IGCCs for production of electricity.
- Complicated gasifier designs (e.g., complicated syngas cooler designs for efficiency): start-ups and operations are often problematic.
- One-off designs, seldom replicated.
- Limited number of gasifiers without spares (complicated designs require more equipment to be spared, making cost of sparing harder to justify).
- Attachment to a power grid with cyclical demands provides alternative backup options and lowers motivation for higher on-stream availabilities.
- Located at isolated stand-alone sites, with little complementary support infrastructure and limited site-based technical knowhow and support.
- Owners unwilling to accept risk as part of EPC contracts (sometimes required by governing boards/agencies), thus driving them toward lump-sum turn-key EPC contracts that significantly increase CAPEX.
- Examples
  - U.S. – Tampa Electric, Wabash River, Southern Kemper, Duke Edwardsport
  - Global – Shell Buggenum, Puertollano, Reliance Jamnagar

Lessons Learned – Learnings from Adversity (2)

- Avoid big leaps in scale-up of first-of-a-kind gasification designs: often leads to operational difficulties or failures.
  - Examples: Southern Kemper IGCC, Reliance Jamnagar, Duke Edwardsport IGCC
- Designs for co-feeds (e.g., biomass and/or wastes with coal) have often been problematic.
  - Gasification rates of co-fed feedstocks can be quite different.
    - Over-oxidation/combustion of faster reacting feeds.
    - Under-conversion of slower reacting feeds (requiring solids recycle).
  - Different physical and chemical properties (e.g., particle size/shape, bulk density, ash fusion temperature, moisture, and contaminant levels) of coal, biomass, and waste feedstocks make it **difficult to find a single acceptable gasifier design**.
  - Conventional or existing feed systems are often problematic, limiting the fraction of alternative feedstocks that can be co-fed.
  - Consistency of feed can often be a problem, affecting operational control.
  - Co-feed projects generally require **specialized designs for each step of the gasification process**: feed systems, gasifiers, and downstream syngas cleanup and conversion steps (introduction of additional contaminants and/or tars).

Key Learnings Summary

- Gasification can be successful and profitable!
- Don't overcomplicate designs – keep them simple.
- Focus on high-value products.
- Attempt to use proven, standardized and replicated designs wherever possible – avoid significant scale-ups of first-of-a-kind technologies.
- Where possible, site projects at integrated plant sites with complementary infrastructure and support.
- Support projects with appropriate and well-skilled technical and support staff and adequate resources.
- Learn from mistakes and adjust designs and procedures to avoid repeating them – focus on continual process improvement.
- Utilize specialized designs for projects involving co-feed materials.
- Perhaps #1 success factor is having a sense of urgency and high-level commitment (focus, resources, staffing) to making the project a success!

R&D Needs for Gasification (1)

- Need for new or improved simple modular replicated gasifier designs, particularly designs targeting co-feed projects.
- New improved designs for consistent co-feed systems.
  - Segregated weigh feeders?
  - Torrefaction of blended co-feeds?
  - Front-end pyrolysis of blended feeds ahead of gasification?
  - Separate gasifiers focused on each feed material, with combined downstream syngas?
- Improved efficiency/effectiveness syngas cleanup systems.
  - Multi-contaminant treatment systems?
  - "Warm" cleanup systems?
  - Advanced sorbents/membranes?

R&D Needs for Gasification (2)

- Water/waste treatment needs, particularly for isolated plant sites.
  - Utilization/recycle of non-potable waters or wastewaters?
  - Site treatment/cleanup of quench water and grey water systems?
  - Site treatment of periodic potentially toxic waste streams, such as high-pressure cleanouts of heat exchangers or spent sorbents/solvents?
- Improved process control systems.
  - Online analytical systems?
  - Use of AI/machine learning tools to improve operational control?
- Supply of adequately trained personnel (from universities, community colleges, technical schools, intern programs), i.e., "new blood" is needed.

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Questions?

Thank You!

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Additional information can be found at:
https://www.netl.doe.gov/coal/gasification

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