Coal Conversion – A Global Perspective

2015 Gasification Systems and Coal & Coal-Biomass to Liquids Workshop

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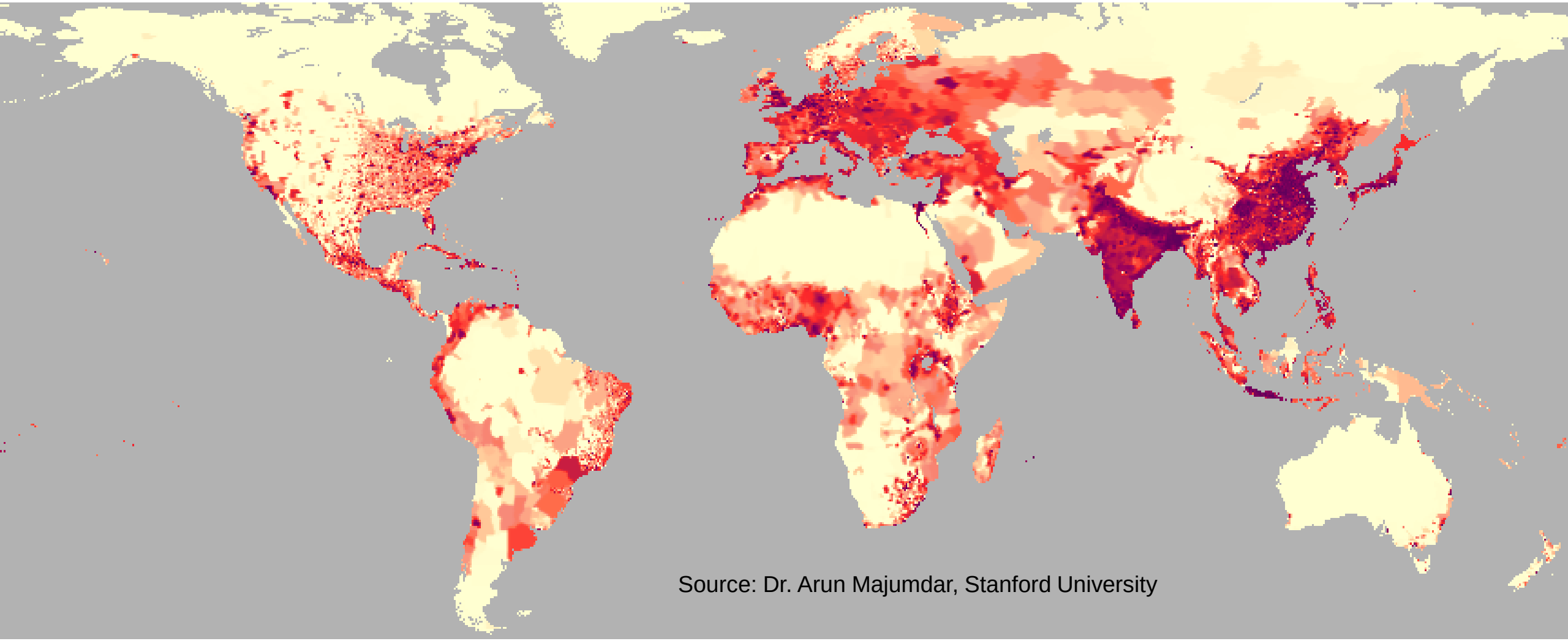
Keynote Address
August 11, 2015

Global Population Continues to Grow



Source: Dr. Arun Majumdar, Stanford University

World Population: 1750s: 0.7B 2013: 7.0B 2050: 9.0B 2100: 10.0B

99% of new population growth in non-OECD Asia and Africa, mostly in urban areas

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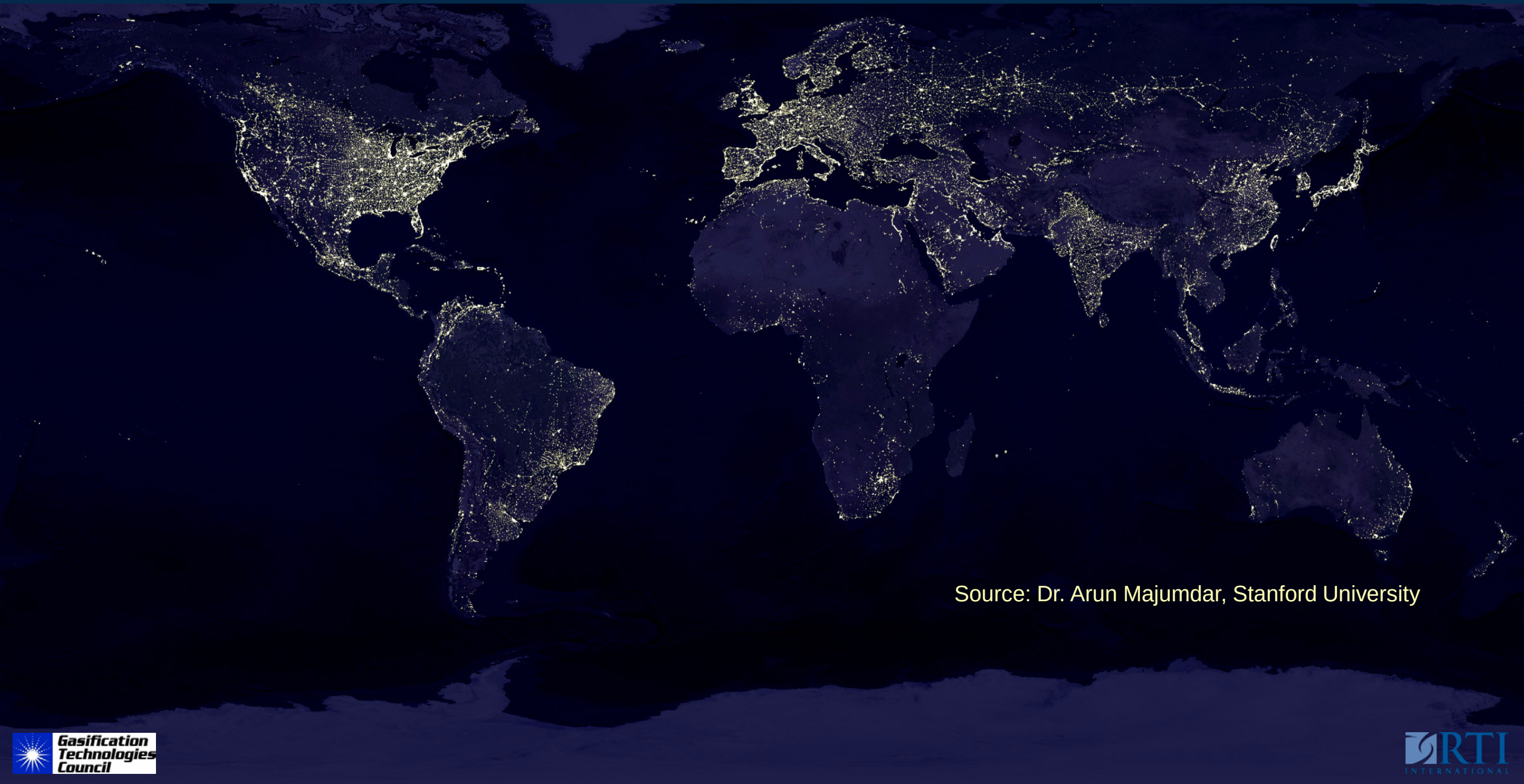
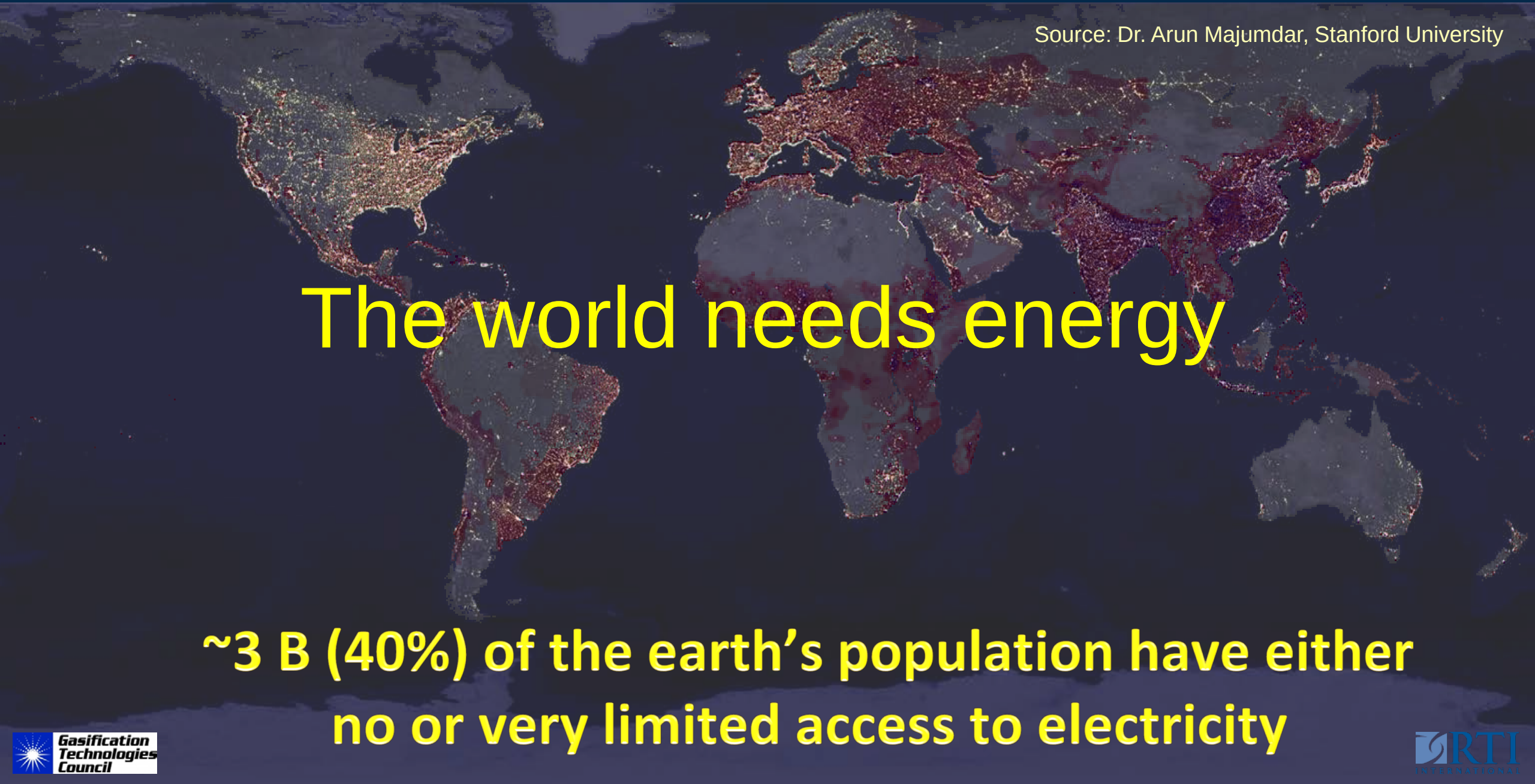
Global Energy Density is Concentrated in More Developed Countries



Source: Dr. Arun Majumdar, Stanford University

Global Energy Density vs. Global Population Density



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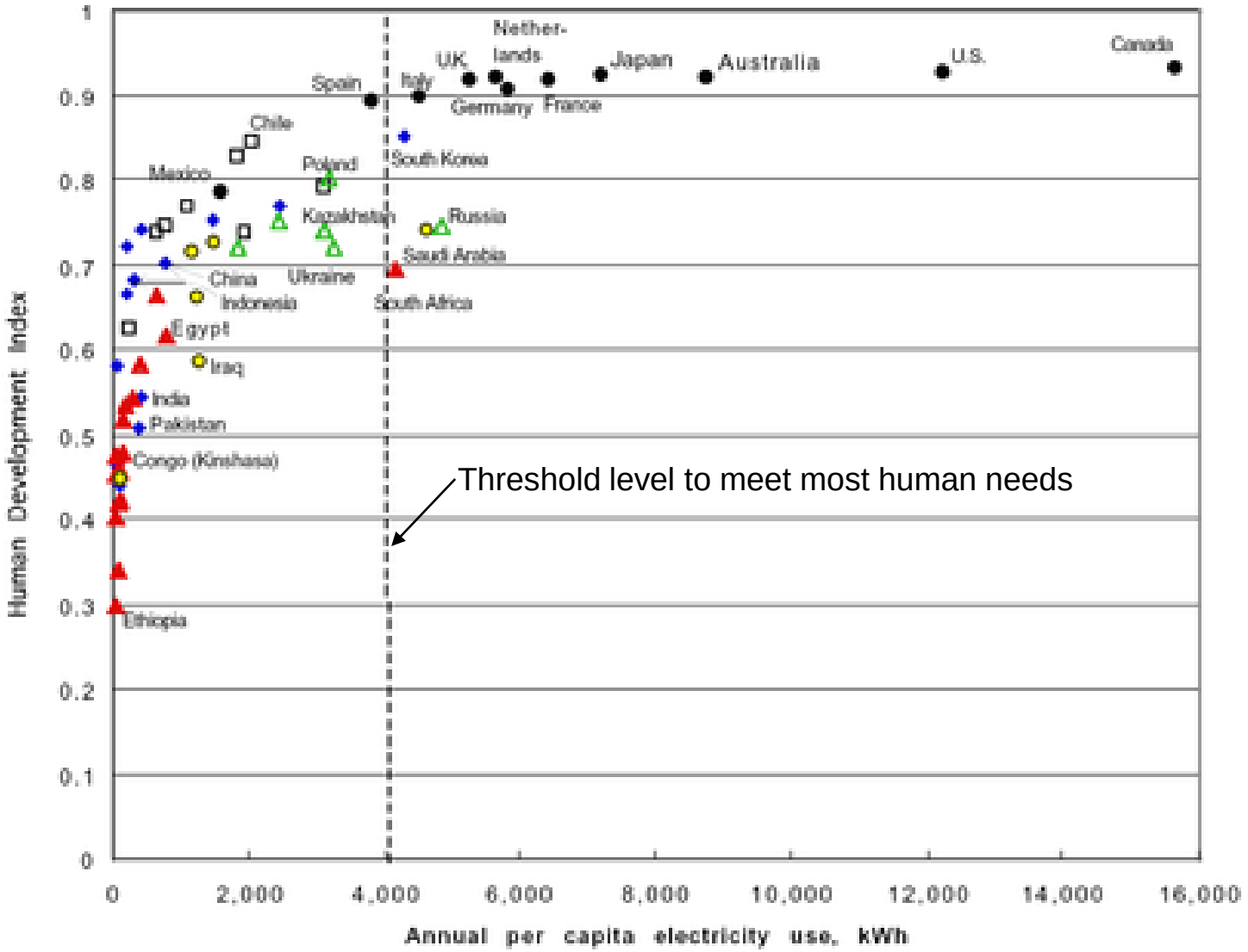
Global Dilemma

How can we provide access to affordable, reliable and clean energy to every human being in the world while avoiding serious damage to our planet?



Source: Dr. Arun Majumdar, Stanford University

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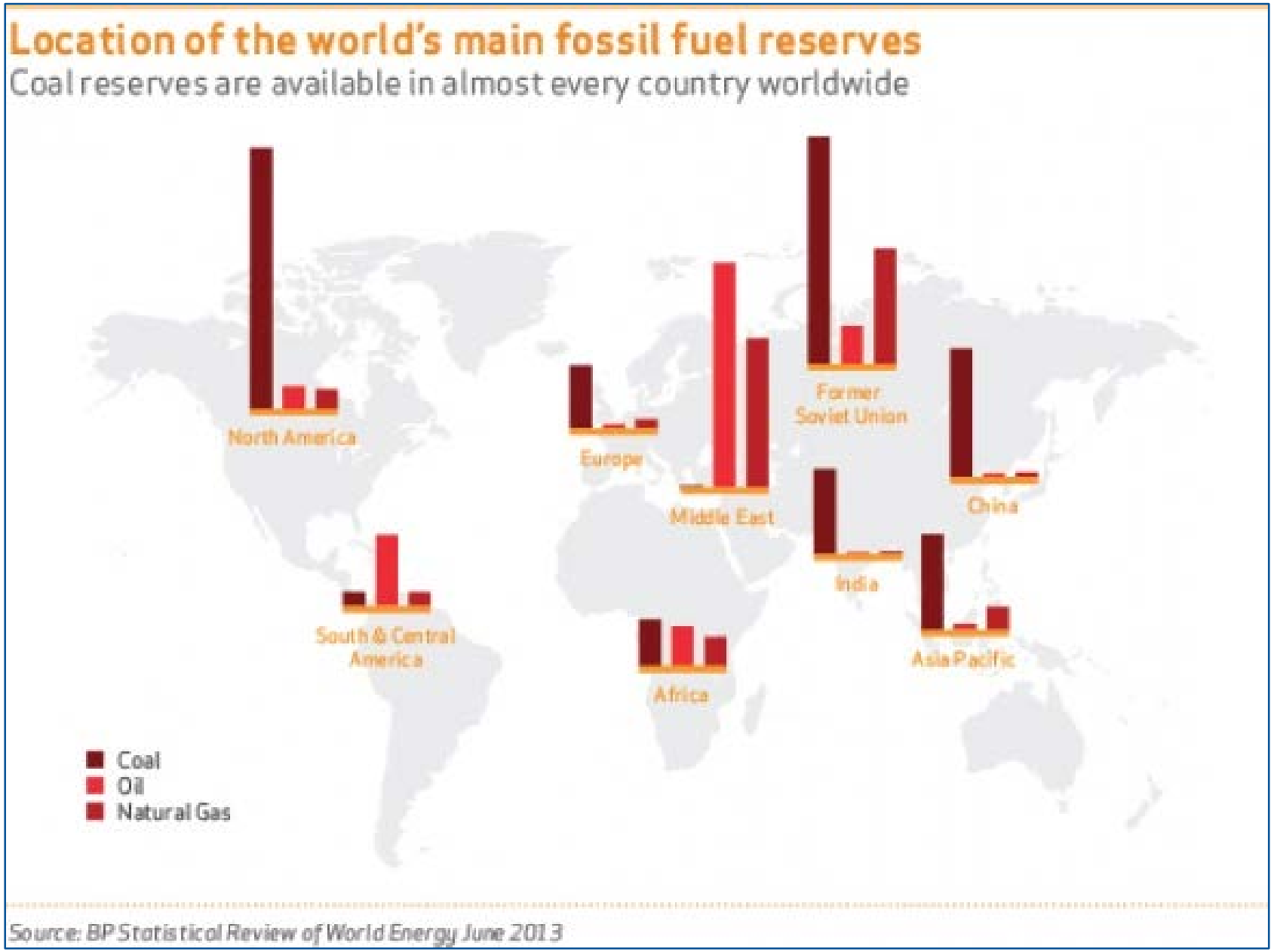
The Solution will Need to Come from Diverse Energy Sources, Including Coal



It has been estimated that there are over 861B tons of proven coal reserves worldwide.

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Factors Impacting Utilization of Coal Conversion Technologies

- Availability of domestic coal or low-cost imported coal
- Relative price of domestic/imported coal versus global gas and oil
- Political/governmental support, or non-support, for coal conversion technologies
- Water requirements and availability (growing concern globally)
- Environmental concerns:
  - Mining of coal
  - Transportation of coal
  - Air and water emissions
  - Carbon dioxide emissions intensity
- Relatively high capital cost of current technologies
- Substantial hurdles to development and deployment of advanced technologies
- The net impact of these factors can vary dramatically from one country to another

A Tale of Two Countries

"It was the best of times, it was the worst of times…"
Charles Dickens - *A Tale of Two Cities*

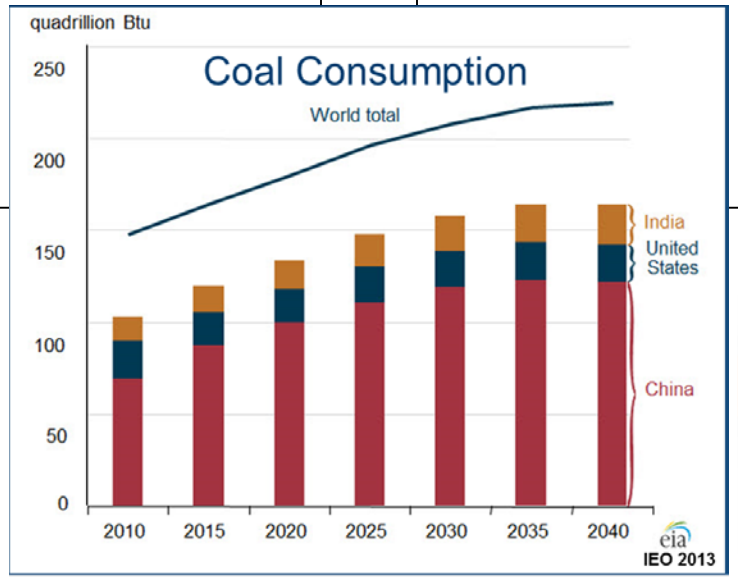
United States of America

- EIA forecasts:
  - Only ~1 GW of new coal gen capacity by 2040
  - 40 GW of coal retirements by 2040, excluding EPA's Clean Power Plan (CPP)
  - 90+ GW of retirements by 2040 w/ EPA CPP
  - Coal < 35% of power gen by 2040 (2013 ~50%)
- NCC forecasts >100 GW coal retirement by 2020
- U.S. coal production fell 16% between 2008 and 2013, may fall another 20-30% by 2040
- Average coal plant is >40 yrs old
- <10 coal/petcoke gasification plants (only 3 of these for chemicals/fuels)

China

- China will add more coal capacity by 2020 than the entire current U.S. fleet
- China to add >500 GW of coal power gen by 2040
- China coal consumption will be >5X U.S. by 2040
- Coal >60% of China power generation in 2040
- China coal gasification growing at >20% CAGR through 2020, but then expected to moderate
- China to add >80 new gasification plants (>400 gasifiers) by 2020, mostly chemicals, fuels, SNG

Note: India will also surpass U.S. in coal consumption by 2030



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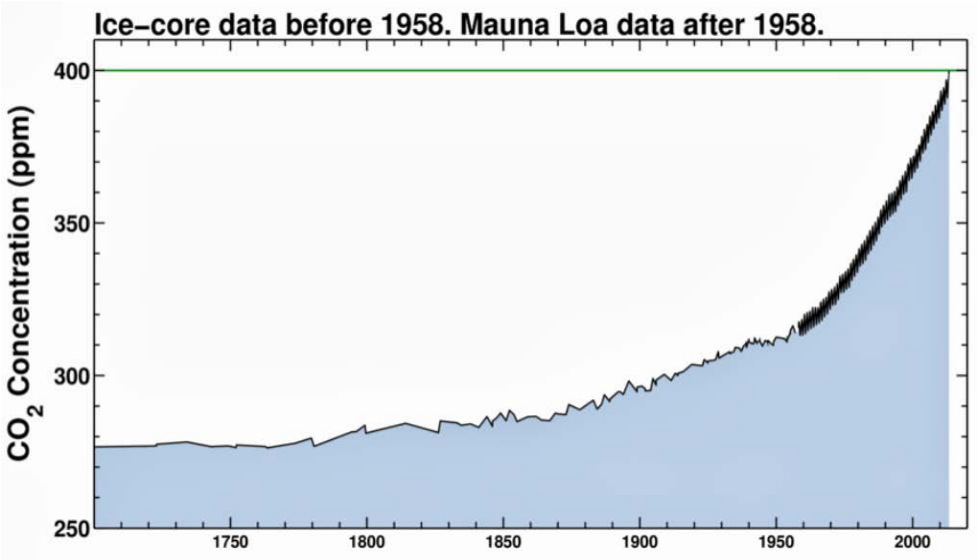
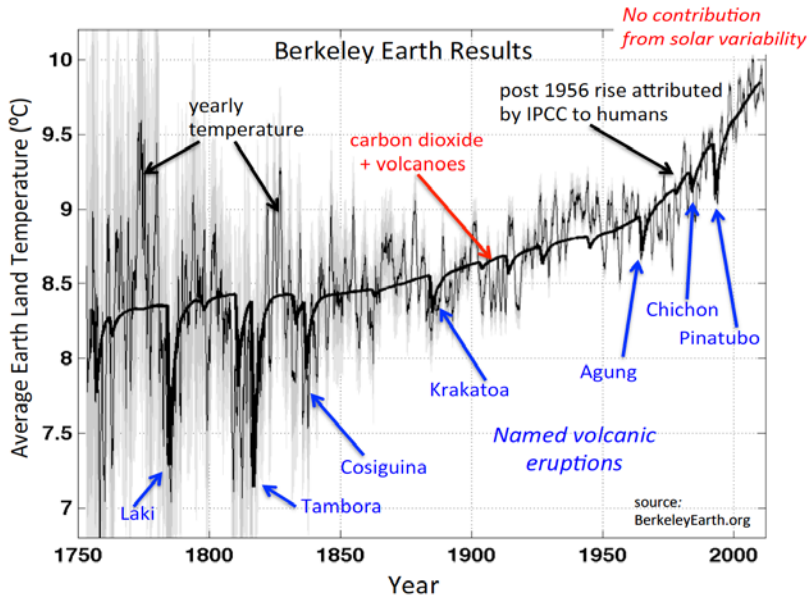
What Does This Imply Regarding Future Carbon Dioxide Emissions?

- The current paradigm will exponentially increase CO_2 concentration in the atmosphere.
- Average global temperatures have been rising for the past few decades and the standard deviation is also increasing (i.e., more low and high extremes).
- Cumulative CO_2 emissions since the Industrial Revolution have been ~ 1 trillion tons over 250 yrs.
- How much more CO_2 can we emit based on known fossil fuel reserves?

  ~ 3 trillion tons over perhaps 75-100 yrs
- The world needs advanced technology that can enable cost-effective carbon capture for utilization of abundant global resources such as coal.
- The best current technology alternative to accomplish that objective is gasification, particularly when utilizing advanced gasification technologies such as those being driven and funded by DOE-NETL.

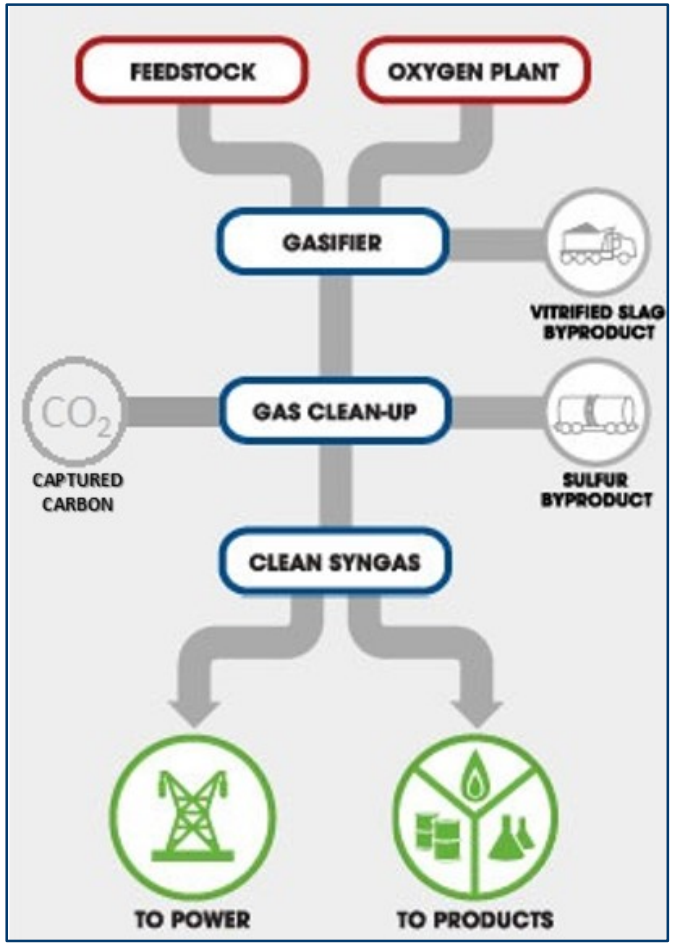




Source: Dr. Arun Majumdar, Stanford University

Gasification – A Critical Part of the Global Solution

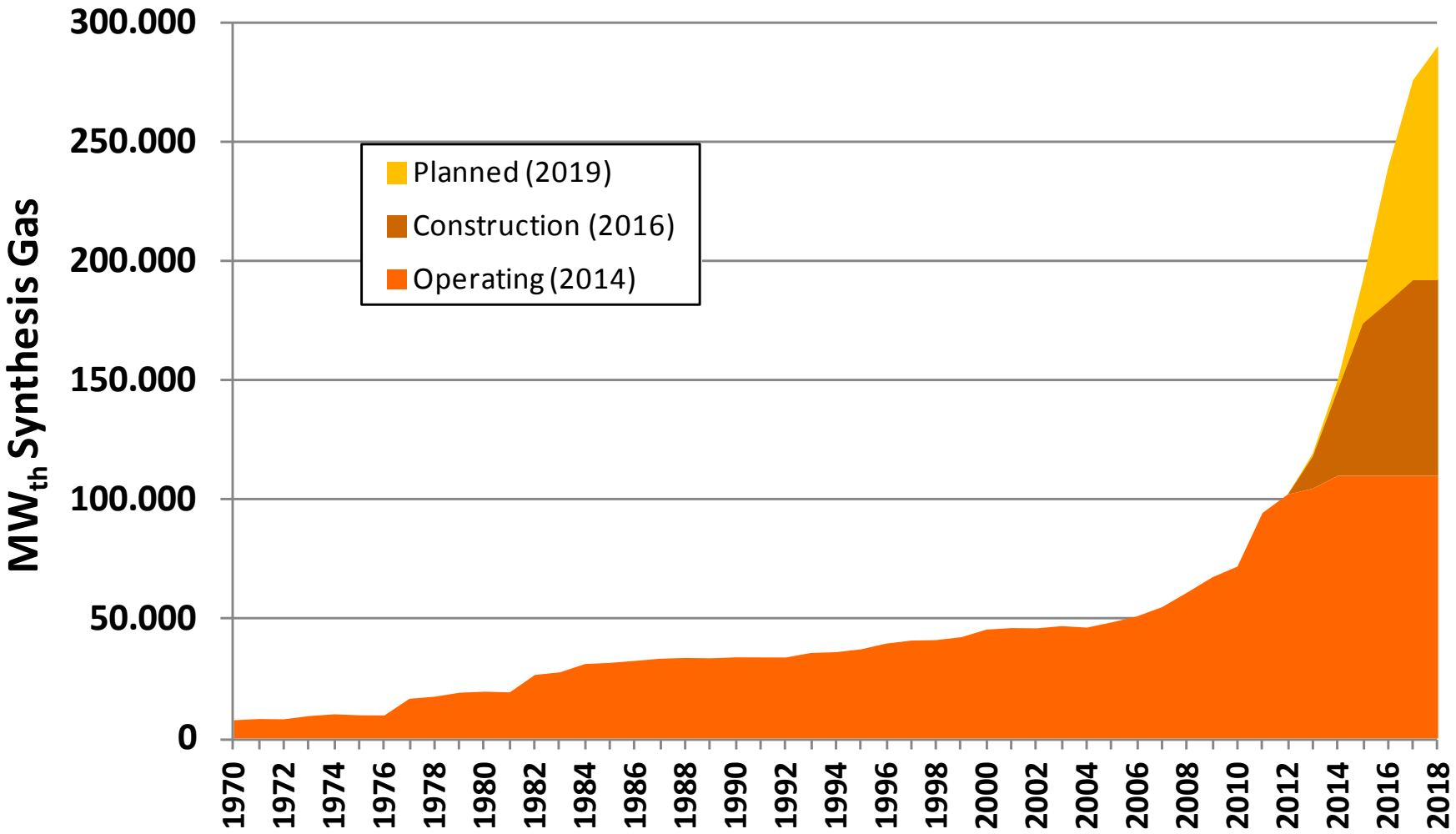
Clean Low-Cost Utilization of Carbon-Containing Feedstocks



Graphic: Gasification Technologies Council

- Gasification is a flexible, reliable and clean energy technology that can:
  - turn a variety of low-value carbonaceous feedstocks, such as coal, petroleum residues, biomass, and wastes into a multitude of high-value products,
  - provide an efficient option for capturing carbon,
  - help a country effectively utilize its natural resources and/or wastes, and
  - provide a source of electric power, fuels, fertilizers, and chemicals needed for economic growth.
- Gasification has been reliably used for more than 60 years in the refining, fertilizer, and chemical industries, and more than 30 years in the electric power industry.

Gasification Has Recently Experienced a Period of Rapid Global Growth



A slowdown is expected ~2020 due to current overcapacity, then a period of continued, though more moderate, growth in the long-term.

Source: GTC Database, 2014

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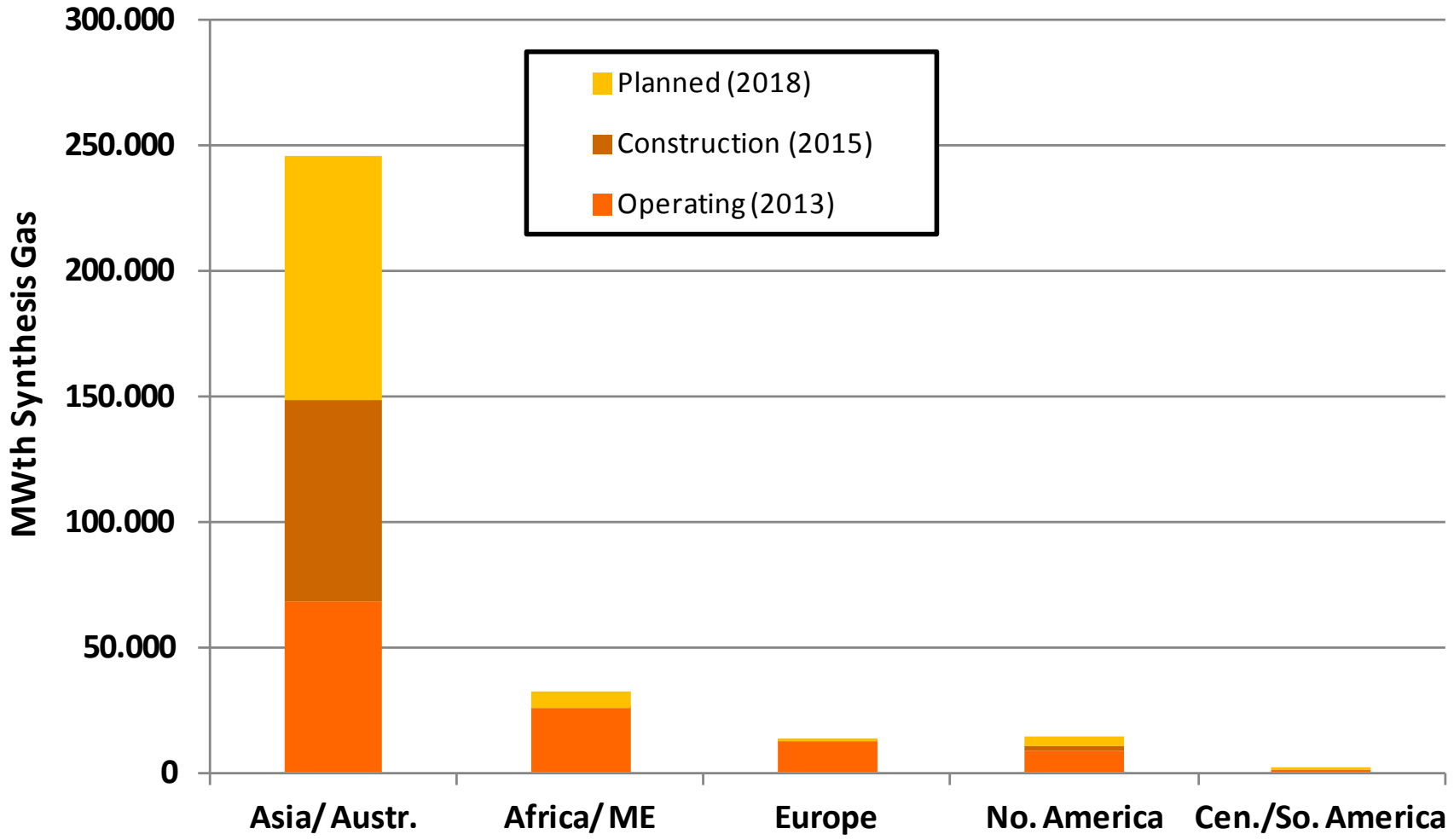
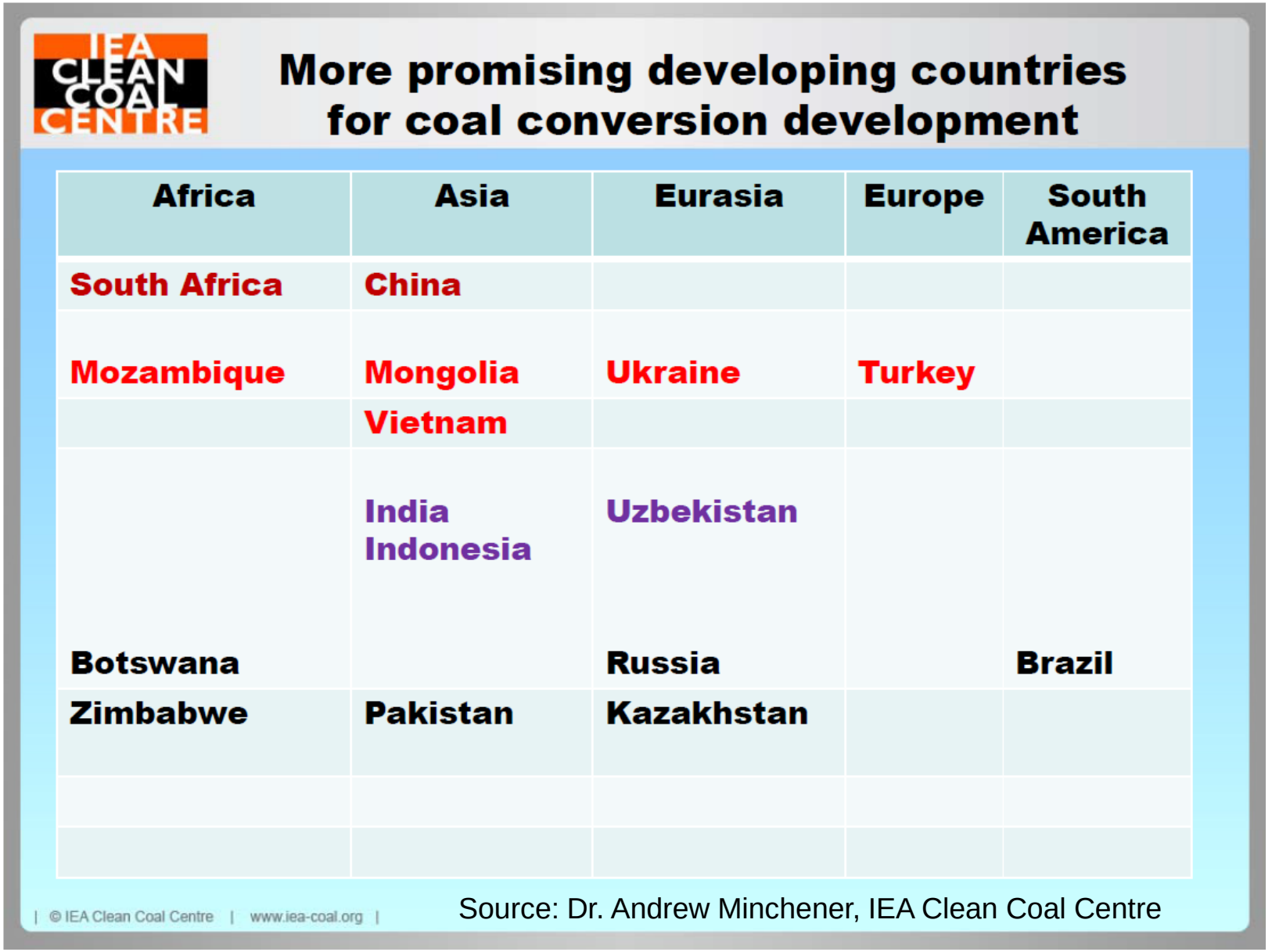
China is the Growth Engine for Gasification



Current growth is primarily in Asia and Africa, with 80-90% of new growth occurring in China.

Source: GTC Database, 2014

Countries with the Most Promise for Coal Conversion Development



Source: Dr. Andrew Minchener, IEA Clean Coal Centre

One Example:
The President of Indonesia recently unveiled an ambitious plan to build facilities to generate an additional 35+ GW of power generation in a span of five years, much of it coal-based, nearly doubling Indonesia's total coal consumption by 2025.

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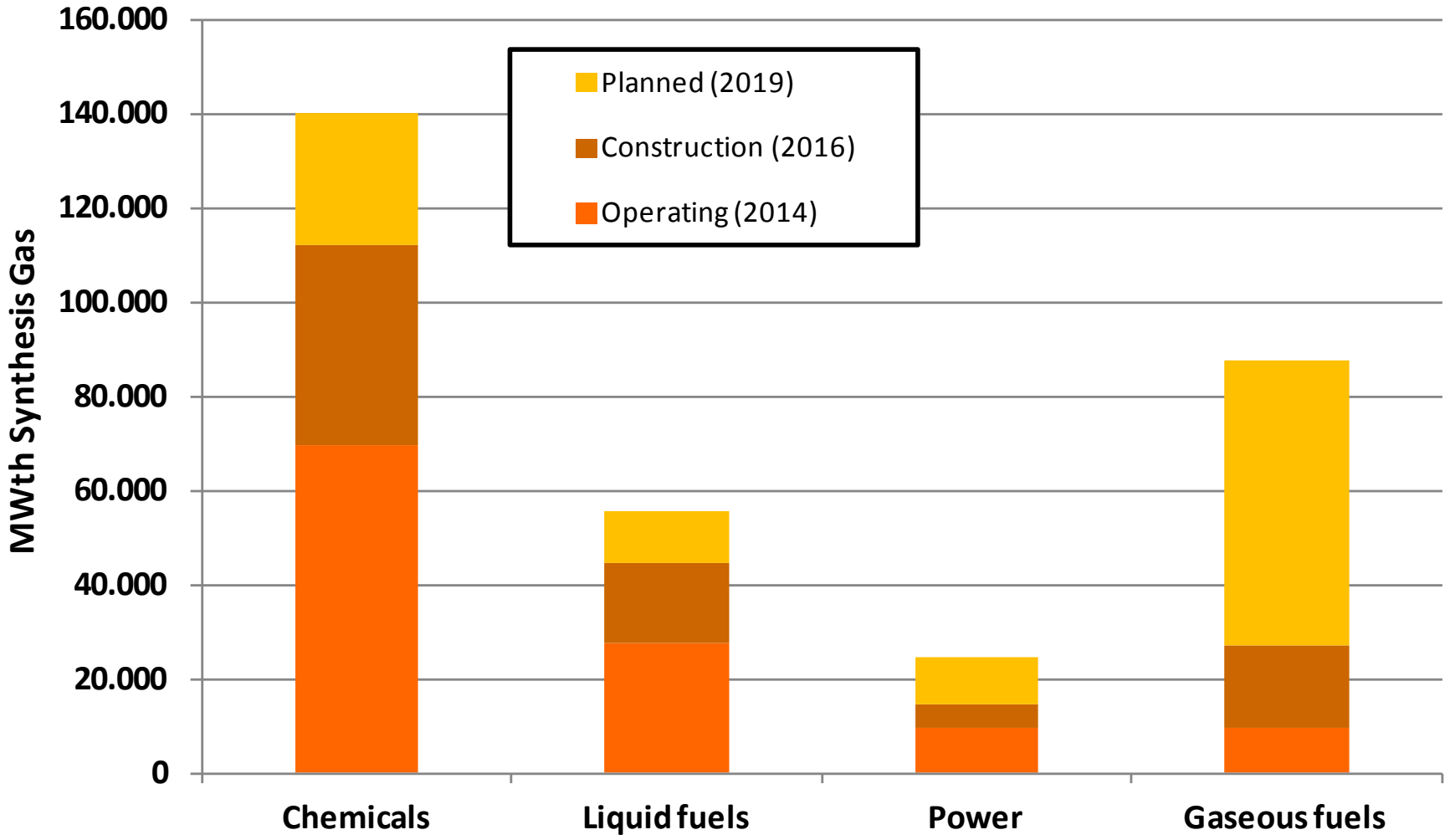
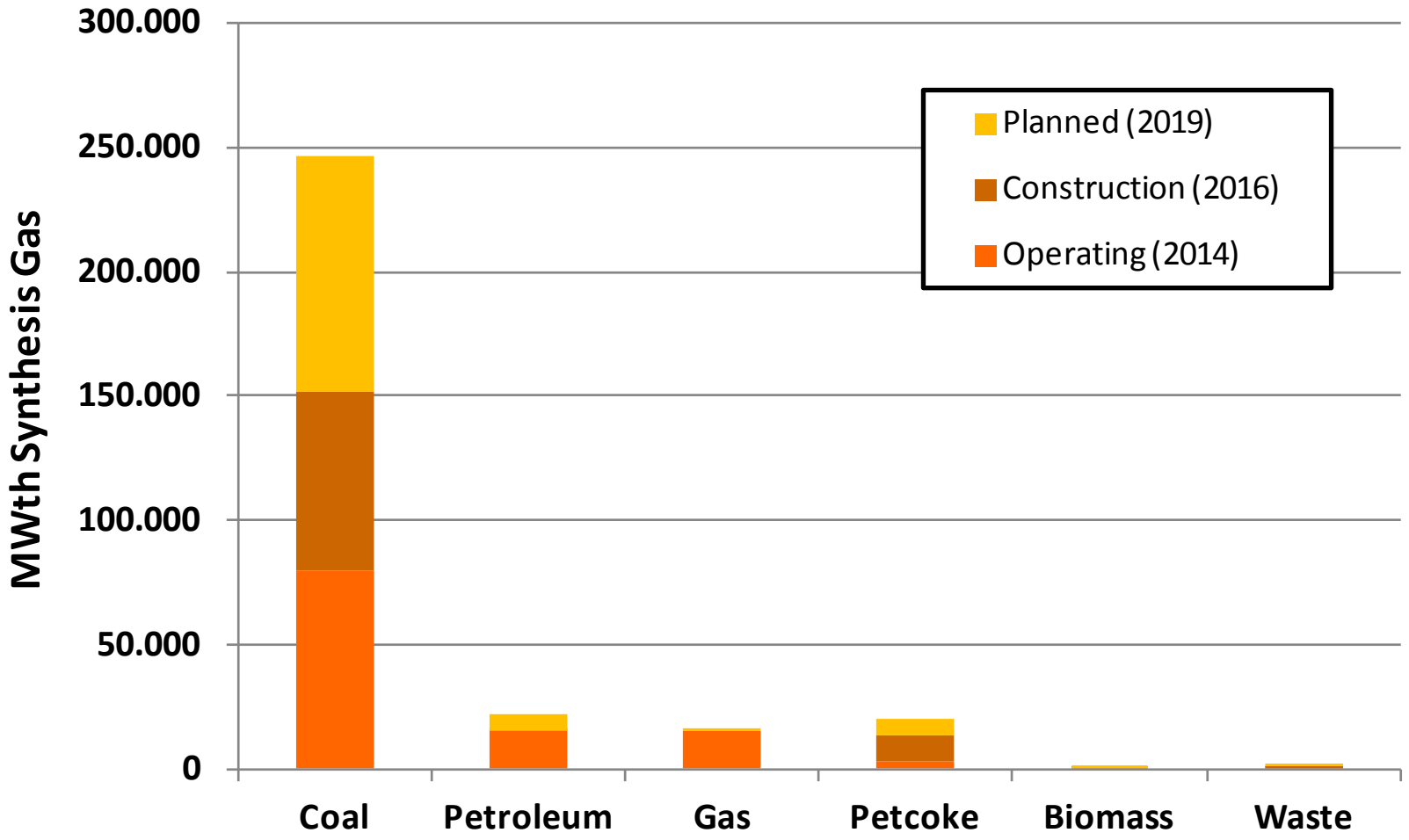
Chemicals and Fuels are the Leading Applications for Gasification



Most growth is in conversion to chemicals, fuels, SNG and H_2, with only moderate current growth in electric power (IGCC).

Source: GTC Database, 2014

Coal Remains the Dominant Feedstock for Gasification



Though coal remains the dominant feedstock for gasification, there has been considerable recent interest in conversion of biomass and wastes (a number of proposed projects, but relatively small in size compared to coal).

Source: GTC Database, 2014

A Number of New Proposed Gasification Projects are Mega-Plants

Top Commercial Coal/Petcoke Gasification Projects (Active or Planned)

Plants	Location	Techno -logy	Gasifiers	MWth Syngas	Start year	Feedstocks/ Products
Sinopec Changji SNG Plant	China	Unspecified	20 + 2	10000	2017*	Coal / SNG
Sinopec Urumqi SNG Plant	China	Unspecified	24 + 4	10000	2017*	Coal / SNG
Yinchuan CTL Plant	China	Siemens	22 + 2	9300	2016*	Coal / FT Liquids
Jamnagar Gasification Plant Phase I	India	E-Gas	10 + 0	8893	2015*	Petcoke / Electricity-SNG-CO-Acetic acid
CPI Yili SNG Phase II	China	Unspecified	20 + 2	7500	2016*	Coal / SNG
Huadian Changji SNG Plant	China	Unspecified	20 + 2	7500	2017*	Coal / SNG
Datang Ningxia SNG Plant	China	SEDIN	45 + 3	7125	2015*	Lignite / SNG
Sasol Synfuels West	South Africa	Lurgi FBDB	40 + 0	7048	1977	Subbit. coal / FT liquids
Sasol Synfuels East	South Africa	Lurgi FBDB	40 + 0	7048	1982	Subbit. coal / FT liquids

Source: GTC Database, 2014

*Planned/under construction

Note that each of these new large projected gasification projects is bigger in overall capacity than either Sasol East or Sasol West!

Top 10 Currently Operating Gasification Projects

Plants	Location	Techno -logy	Gasifiers	MWth Syngas	Start year	Feedstocks/ Products
Pearl GTL	Qatar	Shell	18 + 0	10936	2011	Natural Gas / FT Liquids
Sasol Synfuels West	South Africa	Lurgi FBDB	40 + 0	7048	1977	Subbit. coal / FT liquids
Sasol Synfuels East	South Africa	Lurgi FBDB	40 + 0	7048	1982	Subbit. coal / FT liquids
Datang Duolun MTP Plant	China	Shell	3 + 0	3373	2011	Lignite / Methanol
Shenhua Ningxia Coal to Polypropylene II	China	SEDIN	14+ 2	2500	2014	Coal / Methanol-PP
Shenhua Ningxia Coal to Polypropylene I	China	Siemens	5 + 0	1912	2011	Coal / Methanol-PP
Great Plains Synfuels Plant	United States	Lurgi FBDB	12 + 2	1900	1984	Lignite / SNG
Shenhua Baotou Coal-to-Olefins Plant	China	GE	5 + 2	1750	2011	Coal / Methanol-Olefins
Hexigten SNG Plant	China	SEDIN	12 + 2	1670	2012	Coal / SNG
Rongxin Inner Mongolia Methanol Plant	China	ECUST	2 + 1	1400	2014	Coal / Methanol

Source: GTC Database, 2014

All these top 10 largest operating gasification projects produce chemicals or fuels

Recent Trends in Gasification

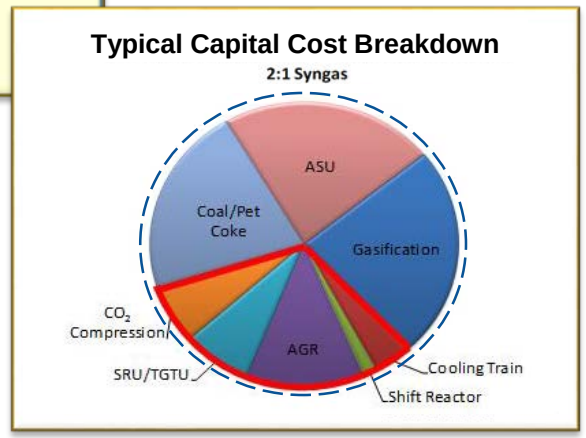
- A number of current new gasification projects, particularly in China and India, are mega-plants aimed at producing SNG, olefins, and CTL.
- However, due to the current global slowdown and lower than normal oil and gas prices, these mega-projects have begun to slow down (and a few have been postponed or cancelled).
- This has led to a desire to retrofit or replace a number of older and smaller gasification plants to extend their life or add incremental capacity, particularly in China.
- IGCC interest has been growing in developing areas, particularly throughout Asia, as the world focuses more attention on greenhouse gas issues.
  - The size of these IGCC's tend to be smaller than in the past (100-300 MW_e).
  - They often utilize aero-derivative syngas turbines which require low CO_2 contents, so some CO_2 capture is often required.
- Interest in biomass and waste gasification is also increasing, particularly in the U.S. and Europe.
- These newer developments are focused on smaller-scale gasification systems, thus reducing capital costs and lowering the viable economy of scale is very important.
- So a bipolar type of market currently exists, large mega-plants and a number of smaller gasification plants, driving gasification technology.

What is Holding Back the Global Utilization of Gasification Technology?

Current Gasification Technology is Versatile and Clean but it is Expensive

Graphics Source:
Eastman Chemical Co.

Conversion to clean power, DRI, or chemicals/fuels



Costs of Each Major Process Block Need to be Reduced

Efficiency Improvements and System-wide Optimization are Ways to Reduce All Elements of Cost

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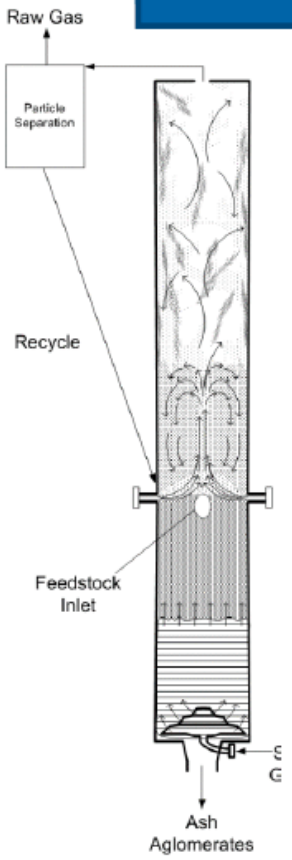
Development Timeline & Cost Present a Hurdle to New Technology Advances

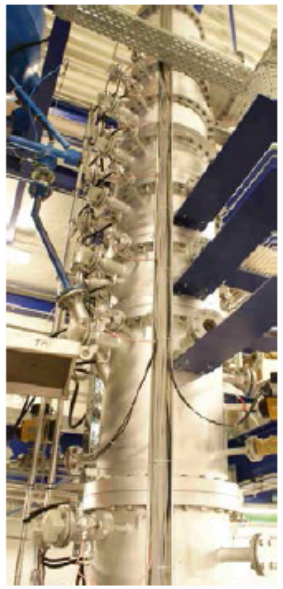
Gasifier Development Timeline

Source: Dr. Bernd Meyer, TU Bergakademie Freiberg

Longer development timelines equate to higher development costs

Theory → Bench-Scale → Pilot → Demo → Commercial





Past:
25 years
e.g. BGL, HTW, AFB, E-Gas, Shell

Today:
15 years
e.g. OMB

Still too long

Reduce development periods for evolution/adaption of existing technology and new approaches

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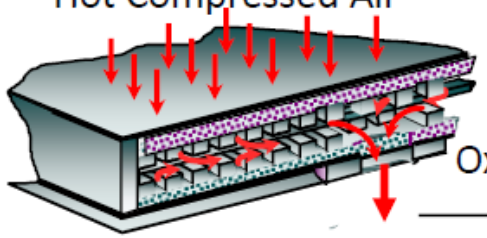
DOE-NETLs Advanced Gasification Program is Focused on Reducing These Barriers

Mature R&D Anticipated Benefits

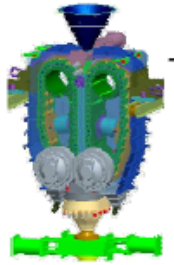
APCI Ion Transport Membrane
$72M ARRA Award – progress made

Hot Compressed Air



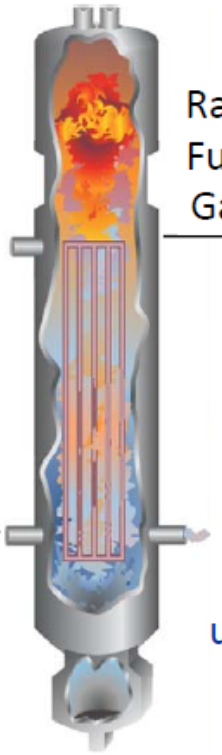
Oxygen

Oxygen Membrane
7% capital cost reduction
5% COE reduction



Feedstock

Coal Feed Pump
1% COE reduction



Raw Fuel Gas

RTI Warm Gas Cleanup
$173M ARRA Award
Successful 50 MWe tests

Warm Gas Cleaning
in combination with
Advanced CO_2 Capture
2.6% pt efficiency increase
12% COE decrease

Clean Fuel Gas

Water-Gas Shift
up to 0.8% pt efficiency increase (preliminary)

H_2-Rich Stream

CO_2

These advanced technologies have been the focus of this conference.

Advances help reduce costs for all applications: power, chemicals, fuels

Summary

- The world needs clean energy.
- That energy must come from diverse resources, including coal.
- The cleanest way to utilize coal is via gasification.
- Gasification is a versatile technology that can turn a variety of low-value carbonaceous feedstocks, such as coal, petroleum residues, biomass, and wastes into a multitude of high-value products and provide an efficient option for capturing carbon.
- Gasification is expected to experience continued, moderate growth in the long-term via a combination of large centralized mega-plants and a number of distributed smaller gasification plants, particularly for cases of retrofits, IGCC, biomass, and wastes.
- The most significant barriers to the effective utilization of gasification are the high capital cost of current technologies and the significant hurdles to develop and deploy new technologies.
- The DOE-NETL Advanced Gasification Program is focused on reducing these barriers through supporting the development of lower cost advanced technologies.

QUESTIONS?

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