Natural Gas Industry Dynamics

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Natural Gas Industry Dynamics

Presentation Objectives:

- Provide some Basics on Natural Gas
- Give a bit of History of NG Industry
- Snapshot of Current Status – here comes LNG!
- Some Ideas about Future – You may be Surprised!!

Natural Gas Industry Importance

Why this talk about Natural Gas?

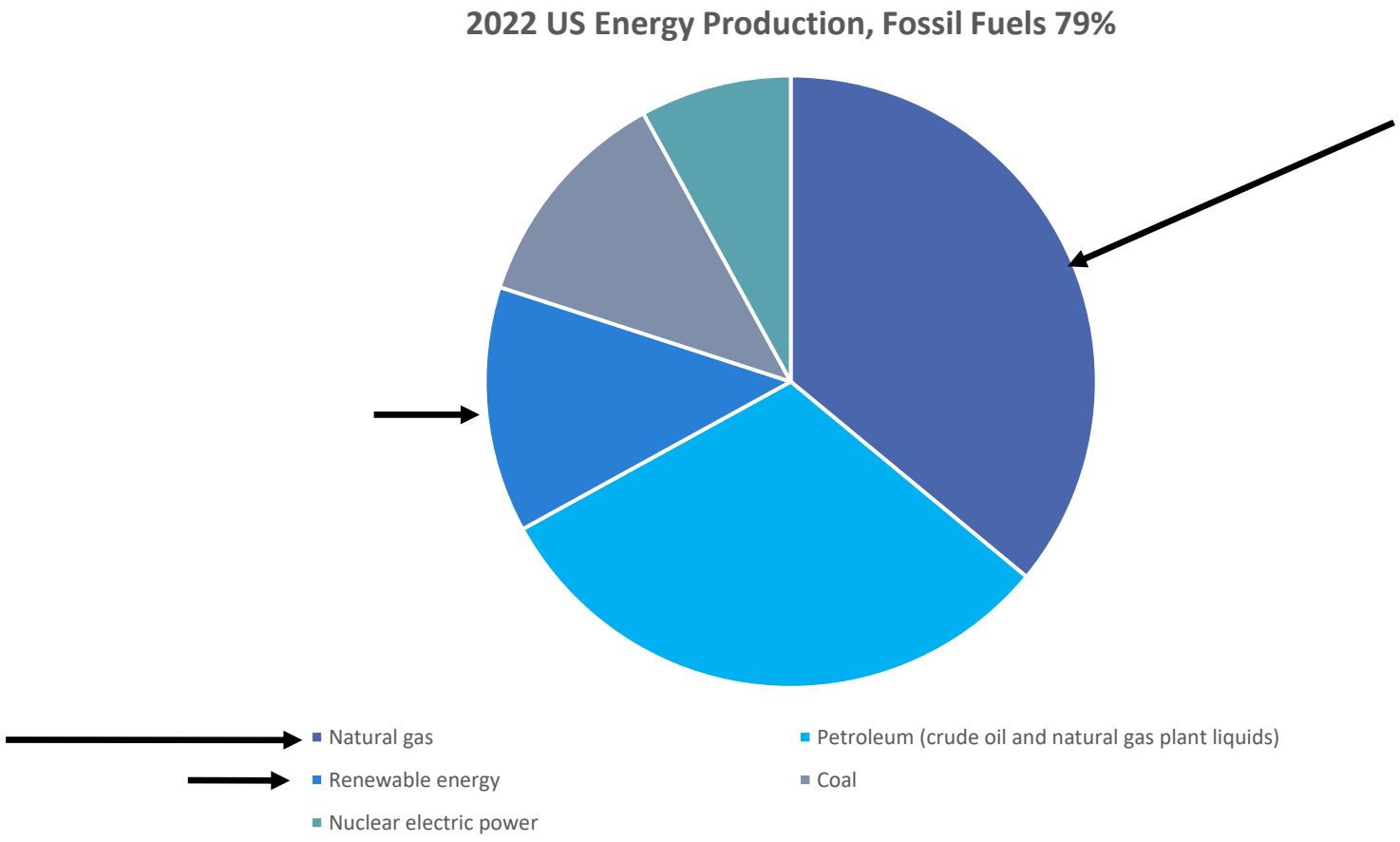
- It is the primary fuel for most refinery and petrochemical manufacturing as well as electric power generation
- For North America (and the Mid-East) it provides very low-cost energy and feedstock advantage
- It is in the news, so here is starting point information to understand and engage

Natural Gas, ESPECIALLY LNG, is booming!

Natural Gas Industry Importance – US

per US Energy Information Agency EIA

Why talk about Natural Gas? - it is the biggest US slice at 36%



Energy Transition: Renewables (much Hydro) are 1/8 of the pie today

Natural Gas Industry Dynamics

Advance Apologies:

- Tremendously broad scope
- Horrific rate of change over last 100 years; exponential the last 20 years
- Necessitates talk is only US focus with Canada and WW side comments

And advance appreciation for public domain sources – especially the International Gas Union

Natural Gas – a Few Basics

- Chemistry - commercial NG is ~95+% methane
- Geophysics - recovered NG is from petroleum/kerogen
- Geology - NG migrates to the earth's surface, UNLESS trapped in a porous reservoir
- Geochemistry - Deeper reservoirs are higher pressure / temperature; petroleum decomposes to smaller molecules
- More Geochemistry - below ~15,000 feet most reservoirs are gas; below ~20,000 feet increasing Carbon Dioxide composition
- Time - most petroleum was created 60-100 million years ago

Considerable variation in original organic material, rock composition and strata

Petroleum & Natural Gas Production

- A ‘BIT’ about Drilling
  - The drill column meets the reservoir at the natural pressure and temperature at depth, so at 10,000 feet ~4,500 PSI and 240 deg F
    - The fluids in the reservoir flow out of the reservoir rock limited by the permeability of the reservoir rock
    - *“Tight Rocks”* have low permeability
  - Fracking is a process that injects fluids under high pressure into tight rocks
    - First selectively used in tight sandstones in the 1950’s
    - Extended to notoriously tight shale strata in the 1990’s
    - Development of Texas Barnett shale natural gas from mid-1990’s
    - Extended to oil bearing shale

Shale: Good Porosity; Very Bad Permeability

Petroleum & Natural Gas Production

- Production Fluids Processing at the Surface
  - The “Fluids” are a foaming mix of oil, gases and water
  - Wellhead pressure varies from thousands of PSI to nil
  - Surface engineering is about separating these components
    - Produced water is salty brine that must be disposed – typically re-injected
    - Crude oil and gas must be separated
      - Crude oil must be stabilized to eliminate C_4 butane and lighter components so the “Dead Oil” can be safely/environmentally moved to market
      - The “raw-make natural gas” is a mix of methane, ethane, propane and butanes with water, hydrogen sulfide and CO_2 impurities
  - Natural **Gas** Processing **Plants** “refine” the raw natural gas
    - There are approximately 550 Gas Plants in the US

Separation, Separation, Separation

Natural Gas Processing

- Gas Processing Plant Operations
  - The role of a Gas Plant varies widely; like refineries, no two are the same
    - Prudhoe Bay Alaska recovers ALL of the gases produced with crude and reinjects the gas into North Slope oil reservoirs; in many places reinjected gas helps maintain reservoir pressure; a lot of natural gas since 1977
    - Most Gas Plants produce pipeline quality commercial natural gas which is essentially almost pure methane
      - Gathering requirements into pipelines generally requires compression to 1,500 PSI
    - Gas plants can also produce **N**atural **G**as **L**iquids "NGLs": ethane C_2, propane C_3, butane C_4 and C_5+… the C_5+ heavies sometimes called natural gasoline
    - If the natural gas field contains enough carbon dioxide, CO_2 can be recovered and used for enhanced oil recovery (example La Barge Wyoming gas field since 1986)

The Natural Gas pressure for my home water heater is 0.5 PSIG

Natural Gas Product Logistics

- Most Natural Gas moves to users/consumers in gaseous phase
- North America has a tremendous NG pipeline and storage network
  - Three Million Miles of US pipelines from producers to consumers
  - Underground storage (salt caverns + aquifers + depleted oil reservoirs) in 48 states
- The US national NG distribution system is *NEW*
  - Prior to 1940, most gas for lighting and heating was produced by coal gasification; a.k.a. Town Gas
  - Just starting 1940 major regional/interregional pipelines started-up
  - Pipeline industry growth has never stopped

Logistics, Logistics, Logistics

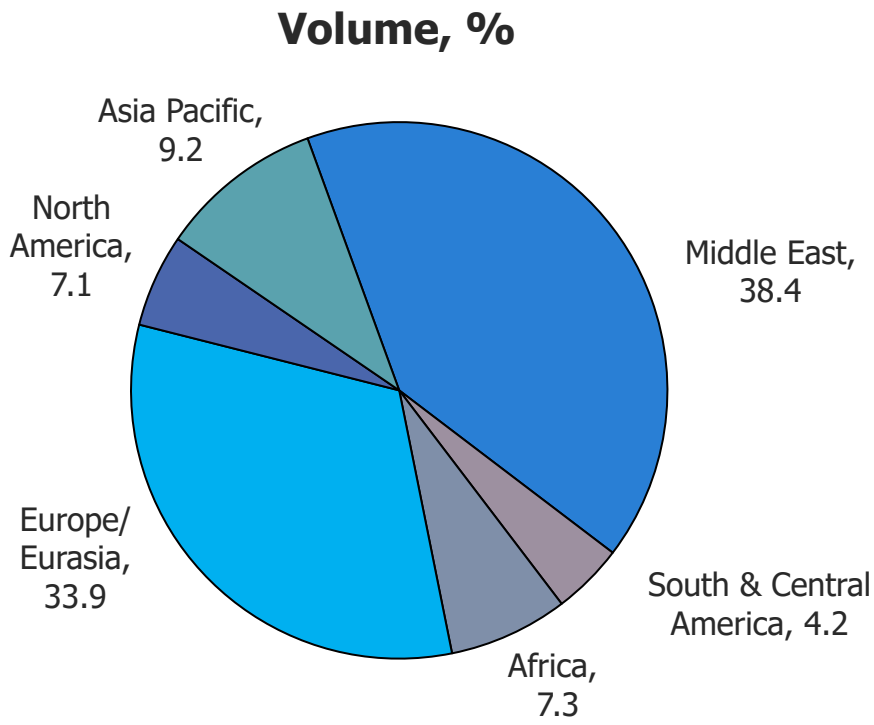
North America Natural Gas Market

- Most industrial Natural Gas is sold under long-term contracts
  - Pricing and min/max volumes were originally fixed
  - Variable pricing has become more common
- Small but growing SPOT NG trading
- NG NYMEX futures trading began in 1983
- Reference US NG trade point is Henry Hub in Erath, Louisiana
  - The HH connects 9 interstate and 4 intrastate pipelines
  - 1.8 BCF/d capacity – about 2 % of the US NG production

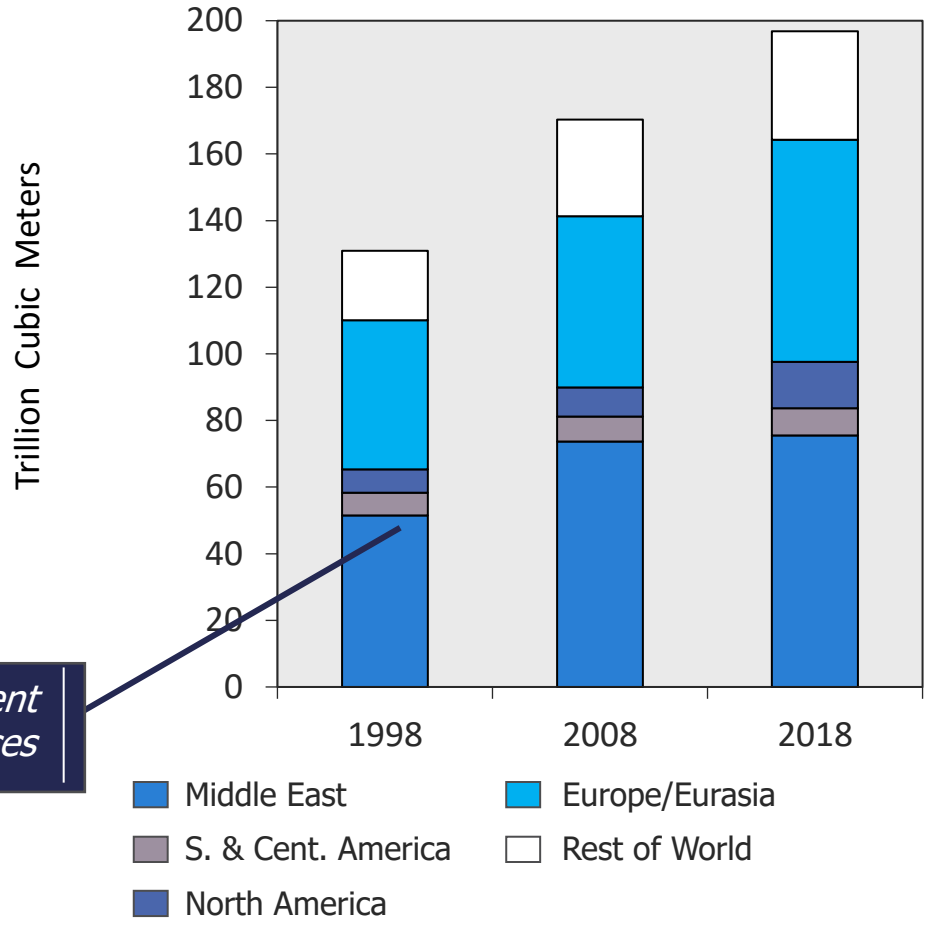
Show me the money!

Distribution of Proved Natural Gas Reserves – per BP

2019



Proved Reserves are based on current technology and prices



Source: BP Statistical Review of World Energy, 2020

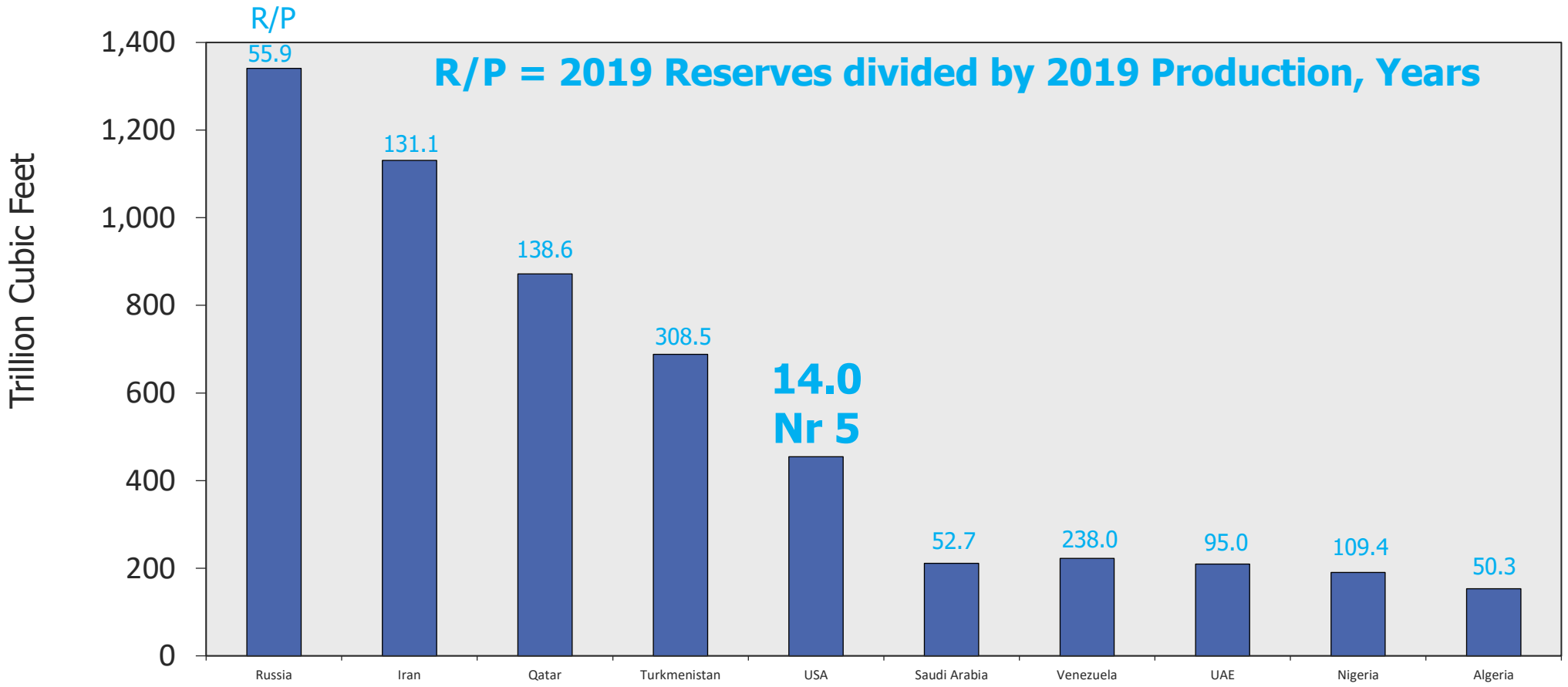
World-Wide Natural Gas Production

- The Top Ten countries produce 71 v% of world volume, BCFPA

	Total NG Bcf PA	
USA	32,508	Nr 1
Russia	23,969	
Iran	8,620	
Qatar	6,287	
China	6,276	
Canada	6,110	Nr 6
Australia	5,419	
Norway	4,038	
KSA	4,010	
Malaysia	2,782	
Top Ten	100,019	
ROW	40,803	
WW	140,822	

Source: BP Statistical Review of World Energy, 2020

World Proved Natural Gas Reserves – per BP



Source: BP 2019 Statistical Review of World Energy, 2020

Natural Gas Liquids

- Gas Plants separate pure NGLs as a co-product of NG production
  - Ethane is gathered and used as a steam cracker feed for ethylene
  - Propane is used as another steam cracker feed OR as a fuel (propane LPG)
  - Butanes can be separated into iso-Butane or normal-Butane
    - iC_4 is a refinery feedstock for alkylation
    - nC_4 is a gasoline blendstock OR a fuel (butane LPG) OR a steam cracker feed
- The HUGE volume of US natural gas production creates volumes of NGLs that give the US advantage in petrochemicals feedstock cost
- Butane in winter gasoline blends lowers US gasoline cost
  - Example in 1Q23, wholesale US butane cost was ~$38/B; gasoline was ~$102/B

US/Canadian NGLs are CHEAP!

International Natural Gas Markets

- Natural Gas is moved by pipeline in gaseous phase to consumers on six continents
  - Intercontinental NG pipelines only exist from North Africa to Europe
- For trans-ocean Natural Gas, **L**iquified **N**atural **G**as is the mode
- Two market trade centers for international LNG
  - Europe: Netherlands Title Transfer Facility, TTF
  - East Asia: Japan-Korean Marker, JKM

LNG – Integrating the World

Liquified Natural Gas Development

- Physical Chemists explored gas-to-liquid phase behavior from 1700-1900 – including methane
- Gaseous methane can be cooled to -260 F (-162 C) and condensed to liquid phase; LNG takes up 1/600th the volume of NG at STP
- First US methane liquefaction of methane began in 1918 - to recover helium
- East Ohio Gas Company built first full-scale LNG plant in Cleveland in 1940
  - Disastrous failure/fire in October 1944
  - Improved low temperature alloys and insulation developed over the next 15 years

Chill, Chill, Chill

LNG Dimensions: CAUTION messy stuff

- For gaseous Natural Gas, primarily measured in **c**ubic **f**eet at STP
  - Depending on situation could be k CF or million CF or billion CF or trillion CF
  - Also reported in Million British Thermal Units (BTUs)
  - ROW uses cubic meters or metric tonnes or joules
- Natural Gas Conversion Factors
  - 1,000 CF is approximately 1 Million BTUs
  - 6 kCF (or 6 Million BTU) is about ONE *equivalent* crude oil or fuel oil barrel
    - So, if NG is trading at $3/Million BTU, that is about $18/OEB
- For LNG which is traded via special tankers often reported in Metric Tonnes
  - One Tonne is about 48 KSCF

My monthly home NG is billed in CSCF

LNG Development

- Britain needed energy supplies by the late 1950s'
  - Economic recovery from WW II austerity/rationing
  - Decline of British coal for fuel and town gas
- First LNG tanker from the US to UK in 1959 <World's first ocean cargo>
  - Small exports to UK developed
- Algerian LNG was commissioned in 1965
  - Cargoes to UK/France
  - Libyan Brega LNG plant was world's newest/largest 1971
    - 4 Trains; 0.8 MTPA LNG per train; 3.2 MTPA Total
- Today's world-class new assets
  - LNG plant trains are each ~6 MT/year or 290 BCF/year
  - LNG biggest Q Max LNG tankers carry up to 120 kTonnes (5.7 Billion SCF)

Q Max are the largest LNG tankers that can call on Qatar

LNG Receiving

- LNG is returned to gaseous state by heating liquid to ~30 deg F or 0 deg C
- Re-gasified natural gas then feeds consumers directly or is fed into local pipeline systems
- LNG tanker receiving, storage and re-gasification facilities are very common in countries needing more natural gas/clean energy
  - Today 48 countries import LNG
- Small LNG tankers are common; facilities are relatively simple
- Low enough LNG prices make LNG imports attractive versus heavy fuel oil

On the other hand, Producing LNG is more Challenging

LNG Production Expansion

- Vast Natural Gas production developed in remote areas
  - Qatar
  - Indonesia
  - Australia
  - Peru
  - Trinidad
  - Papua New Guinea
- LNG plant and tanker designs improved, lowering investment costs
- Clean burning Natural Gas and economic growth have accelerated demand
- Pre-Shale Gas developments projected the USA would need LNG IMPORTS

Grow, Grow, Grow

LNG Capacity 2019

- International Gas Union 2020 World LNG Report – 20 LNG Exporters

	Capacity	MTPA	% of WW	Bcf/d	Bcf PA	
Australia	1	86.0	20.5%	11.3	4131	
Qatar	2	77.1	18.4%	10.1	3703	
USA	3	37.8	9.0%	5.0	1816	
Malaysia	4	30.5	7.3%	4.0	1465	
Indonesia	5	26.6	6.3%	3.5	1278	
Russia	6	26.6	6.3%	3.5	1278	
Algeria	7	25.5	6.1%	3.4	1225	
Nigeria	8	22.2	5.3%	2.9	1066	
Trinidad	9	14.8	3.5%	1.9	711	
Egypt	10	12.2	2.9%	1.6	586	
Oman	11	10.4	2.5%	1.4	500	
Brunei	12	7.2	1.7%	0.9	346	
PNG	13	6.9	1.6%	0.9	331	
Yeman	14	6.7	1.6%	0.9	322	not operating
UAE	15	5.8	1.4%	0.8	279	
Angola	16	5.2	1.2%	0.7	250	
Peru	17	4.5	1.1%	0.6	216	
Norway	18	4.2	1.0%	0.6	202	
Eq. Guinea	19	3.7	0.9%	0.5	178	
Libya	20	3.2	0.8%	0.4	154	shutdown 2011
Cameroon	21	2.4	0.6%	0.3	115	
Argentina	22	0.3	0.1%	0.0	14	
TOTAL		419.8	100.0%	55.2	20163	

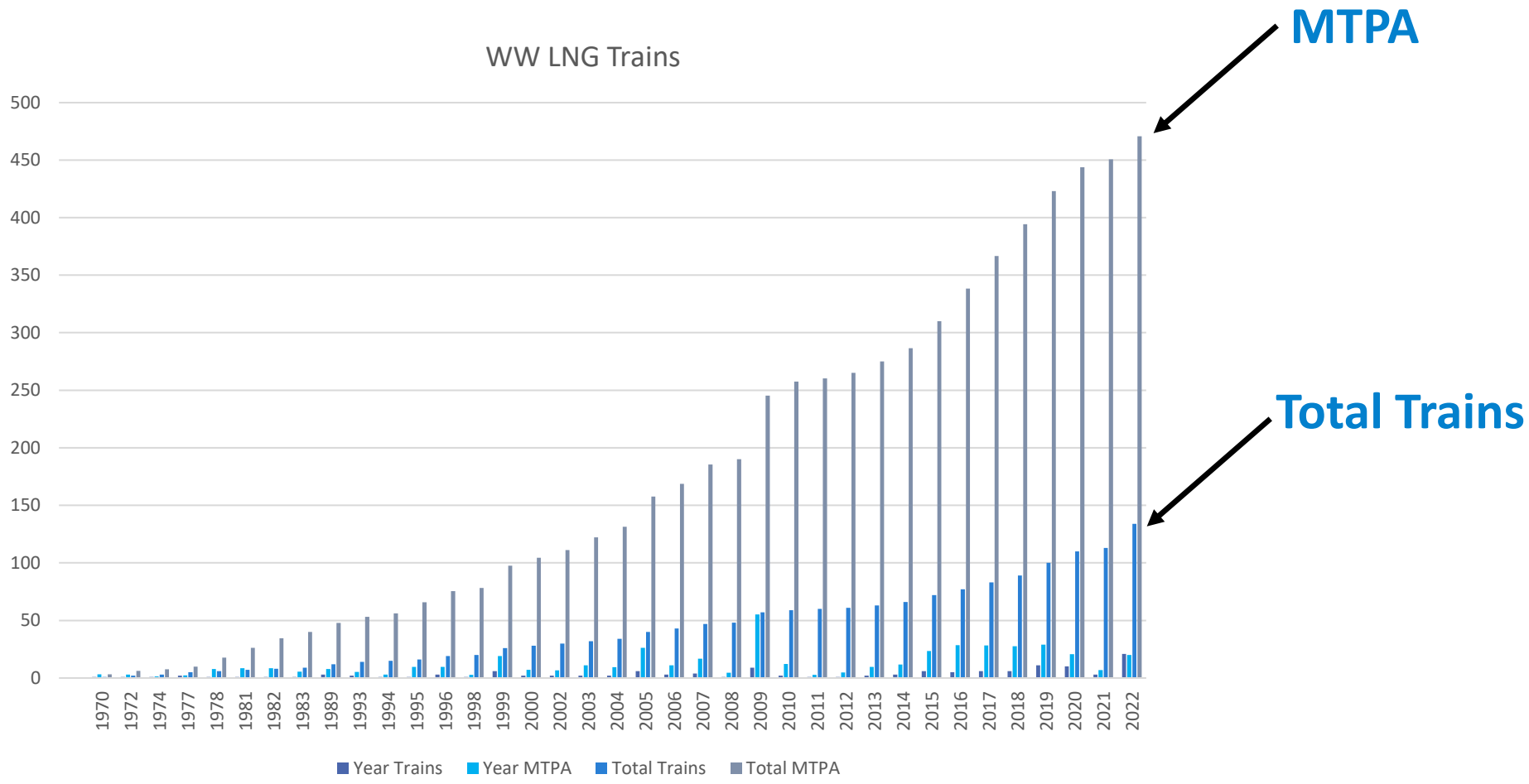
LNG Capacity Update

- International Gas Union April 2023 World LNG Report
- There remain 22 countries with LNG production capacity (19 are operating)
- WW LNG MTPA production grew
  - WW to 472 in 2022 from 420 2020; 350 2016
  - Capacity increased in 2022 in five countries; a few others decreased
    - Australia +1.6
    - Malaysia +1.5
    - Algeria +3.4
    - Russia +1.1
    - **USA INCREASED +48.6** – 2022 US LNG capacity now at 86 MTPA OR about 12% of US TOTAL NG production
  - The USA moved from distant 3rd to close 2nd place, now just behind Australia

Who has the gas?

LNG Capacity Update IGU 2023 Report

- The growth of LNG Capacity to 2022



WW Capacity DOUBLED 2009-2022, MTPA

LNG NEW Capacity from 2022

- WW Capacity grew by 27% from 2016-2022 – 6 Years
- WW Capacity will GROW another 27% 2022-2026 – next 5 Years
- 2023 approval/construction of 23.5 MTPA more capacity for 2024-2026 start-up
- Some projects of interest:
  - YE 2024 ExxonMobil/Qatar Petroleum Golden Pass, Port Arthur, Texas
    - Original LNG IMPORT plant started-up 2010
    - Three 6 MTPA trains; 18 MTPA or about 3% of total US NG production
    - LNG production expansion cost ~$10 Billion US
  - 2025+ LNG Canada, Kitamat, British Columbia
    - Largest private investment in Canadian history; Montney BC NG field
    - JV of 5 companies: Shell, Petronas, PetroChina, Mitsubishi, Korea Gas
    - $40 Billion US; 2025 start-up; 14 MTPA; 2 trains

LNG Longer Range NEW Capacity

- 2026+ Pre-Final Investment Decision some 997 MTPA more capacity
  - If so, that's TWICE the existing 2022 capacity
  - Mostly USA (333), Canada (230), Russia (137) and Australia (46) MTPA
  - How many will be funded?
- 2028+
  - Convert LNG facilities to Hydrogen?
- 2050+
  - Renewables totally replace fossil fuels and nuclear?

Roughly $1-2 Billion US investment per 1 MTPA LNG Capacity

wildly dependent on location; excludes NG feed system and marine shipping facilities

Natural Gas Pricing

- Pipeline NG to consumers and to LNG plants is contracted on regional markets
  - North America price is “gas-on-gas” (GOG)
  - Europe and Asia Pacific formerly tied to oil price (OPE = Oil Price Escalation)
    - Increasingly some trade in “gas-on-gas”
    - A/P mostly long-term contracts
    - Europe has been heavily in spot LNG market with Western sanctions disrupting Russian supply
- LNG premium over North America for production and shipping
  - A/P trade price BTU equivalent is 3-4 x US Henry Hub price
  - Europe trade price differential has varied wildly
    - Exposure to spot market
    - Buying cargoes out of A/P market

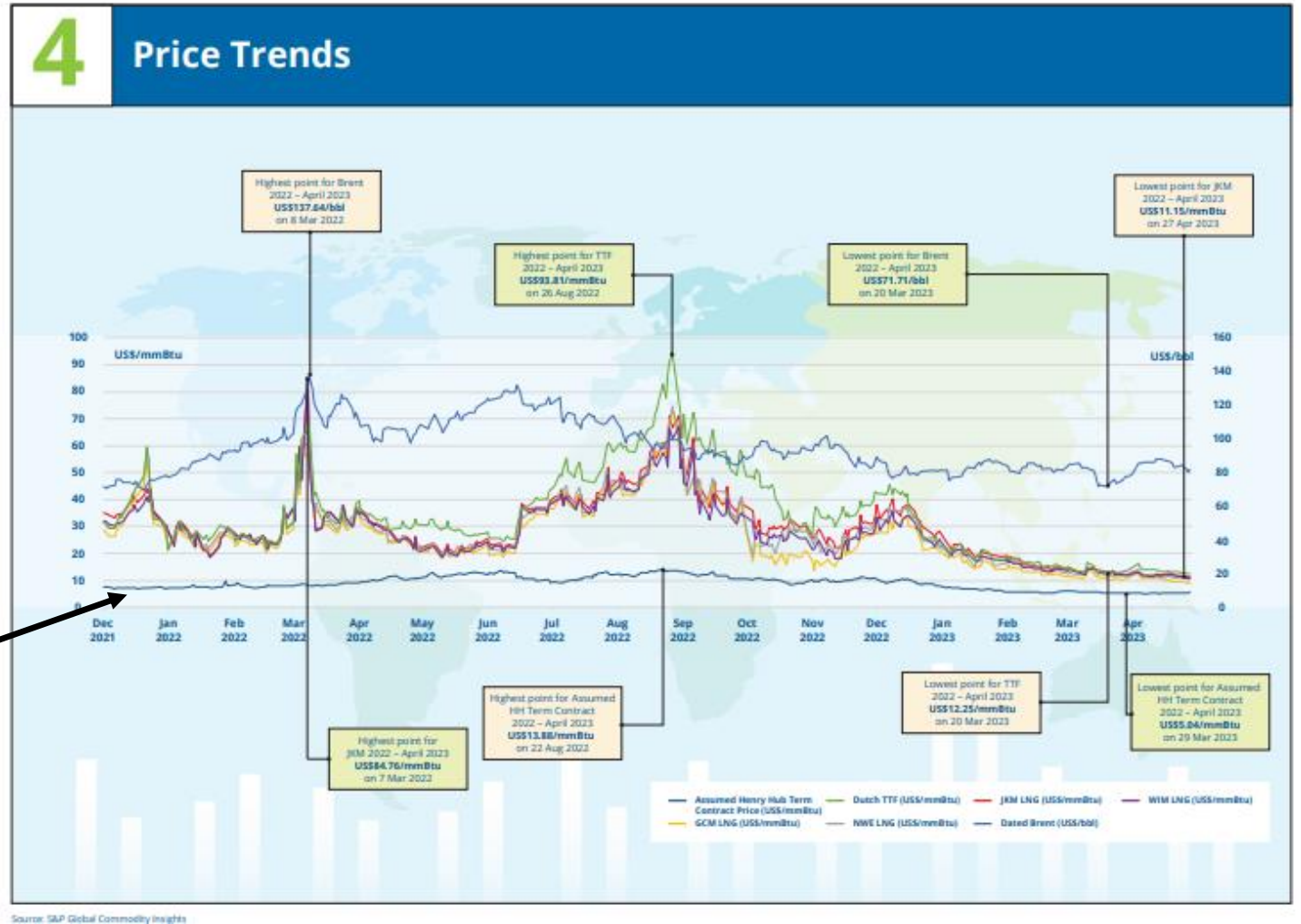
Natural Gas Pricing

- Market prices normally float up and down with higher Northern Hemisphere winter demand

- Historic trends were disrupted with Western sanctions on Russian NG since 1Q2022
    - Market turmoil with Europe scrambling to buy SPOT LNG to cover normal winter energy demand
    - New LNG production capacity helped a little bit
    - Most of LNG to Europe was bought away from Asia contract owners
    - Result was massive switching to coal – record high coal prices

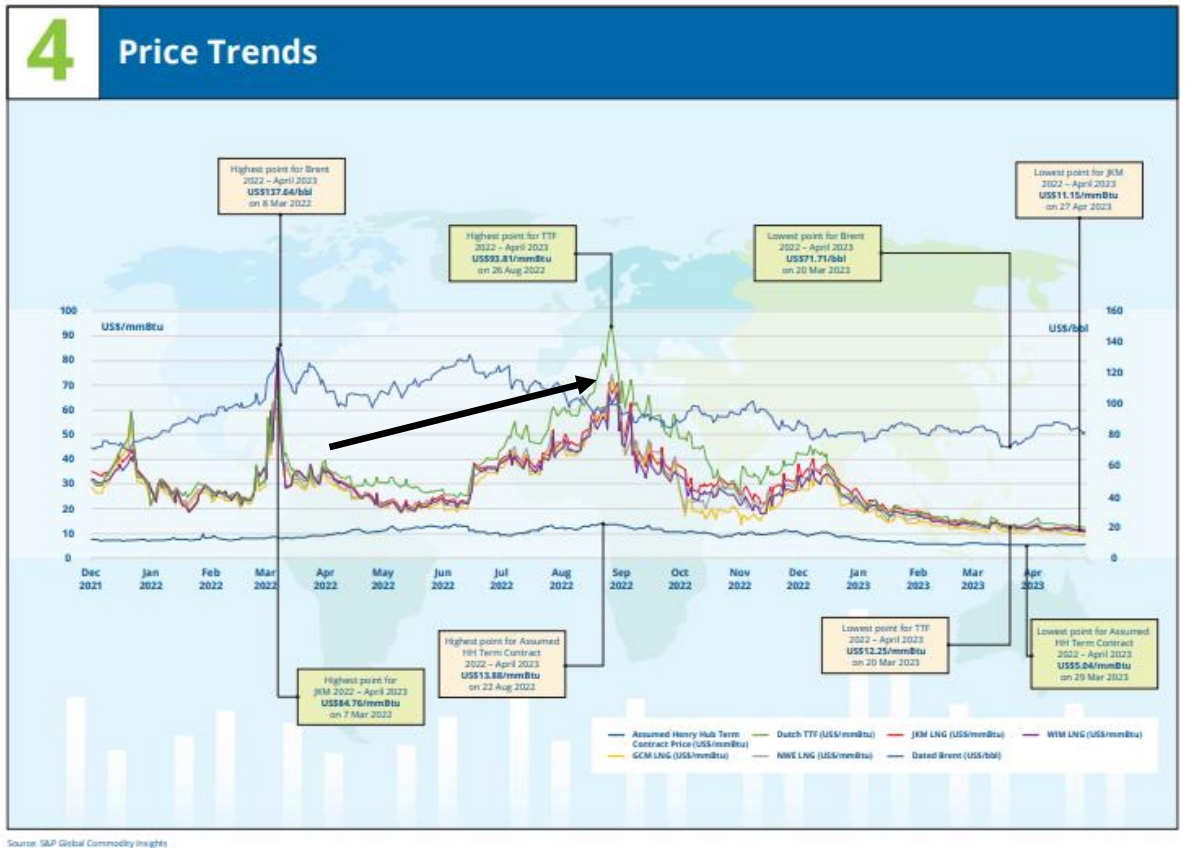
Natural Gas Pricing Havoc Since 1Q22

- Look at North America Henry Hub term prices – US/Canada relatively calm; stayed under $10/Million BTU



Natural Gas Pricing: Havoc Since 1Q22

- Panic in Europe drove TTF price to record high US$93/Million BTU; the US price spot price tracked, but US peaked at ~$9+/Million BTU



TTF is the Dutch Title Transfer Facility

Natural Gas Low-Carbon Solution?

- Methane CH_4 Natural Gas is the cleanest, lowest carbon, lowest cost - reliable energy source
- Natural Gas CO_2 emissions are much lower than oil or coal or biomass
- Europe and a few other regions have established Carbon **E**missions **T**rading **S**chemes
  - The EUR ETS market prices CO_2e in Euros/MeTonne
  - Website Carbon Price Viewer - Ember (ember-climate.org)
- IF NG replaces Coal, a trading credit is generated for NG
  - Save coal CO_2 emissions; incur NG CO_2
  - If CO_2e ETS is 100 Euro/tonne, then ~**4-7 Euro/Million BTU net credit**

Natural Gas - Back to the Future

- Many SIGNIFICANT Future Factors
  - Global population/economic growth (or decline?)
    - Especially growth in China and India – huge populations; huge growth potential
    - Impact of declining EUR and Japan populations and US?
  - Geo-Politics (If/when?)
    - Resume open trade with Russia
    - Economic investment risk: Venezuela, Argentina, Africa, others
  - Path of Carbon Emissions reduction world-wide
    - More (or less) nuclear power
    - Carbon capture and storage
    - Wind/Solar/Battery Energy Storage development
    - Carbon Trading
  - Capital Investment

Natural Gas – Wrap-Up

- Methane, the main component of natural gas, is a simple molecule
- Natural Gas has a long history, much of it started 60+ million years ago
- Most of Natural Gas industrial development has occurred in the past 100 years
- Natural Gas is CLEAN energy; its' abundance and technological/commercial development have made Natural Gas the choice as growing reliable energy source
- Tremendous future development, especially world-wide LNG trade over the next decade - 2032
  - Decade potentially DOUBLING LNG volumes versus 2022

Natural Gas and LNG Information Resources

Acknowledgements:

- Peer reviews by Greg Marshall, Darrel Mosier, Gary Robbins, Kiran Sathaye
- Technical and graphics assistance by Olivia Lyons
- BP Statistical Review of World Energy
- International Gas Union – IGU 2023 World LNG Report
- United States Energy Information Administration
  - **www.eia.gov/energyexplained/natural-gas**
  - **(EIA) U.S. energy facts - data and statistics - U.S. Energy Information Administration**

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Natural Gas – Wrap-Up