KINDER MORGAN

EIM Panel

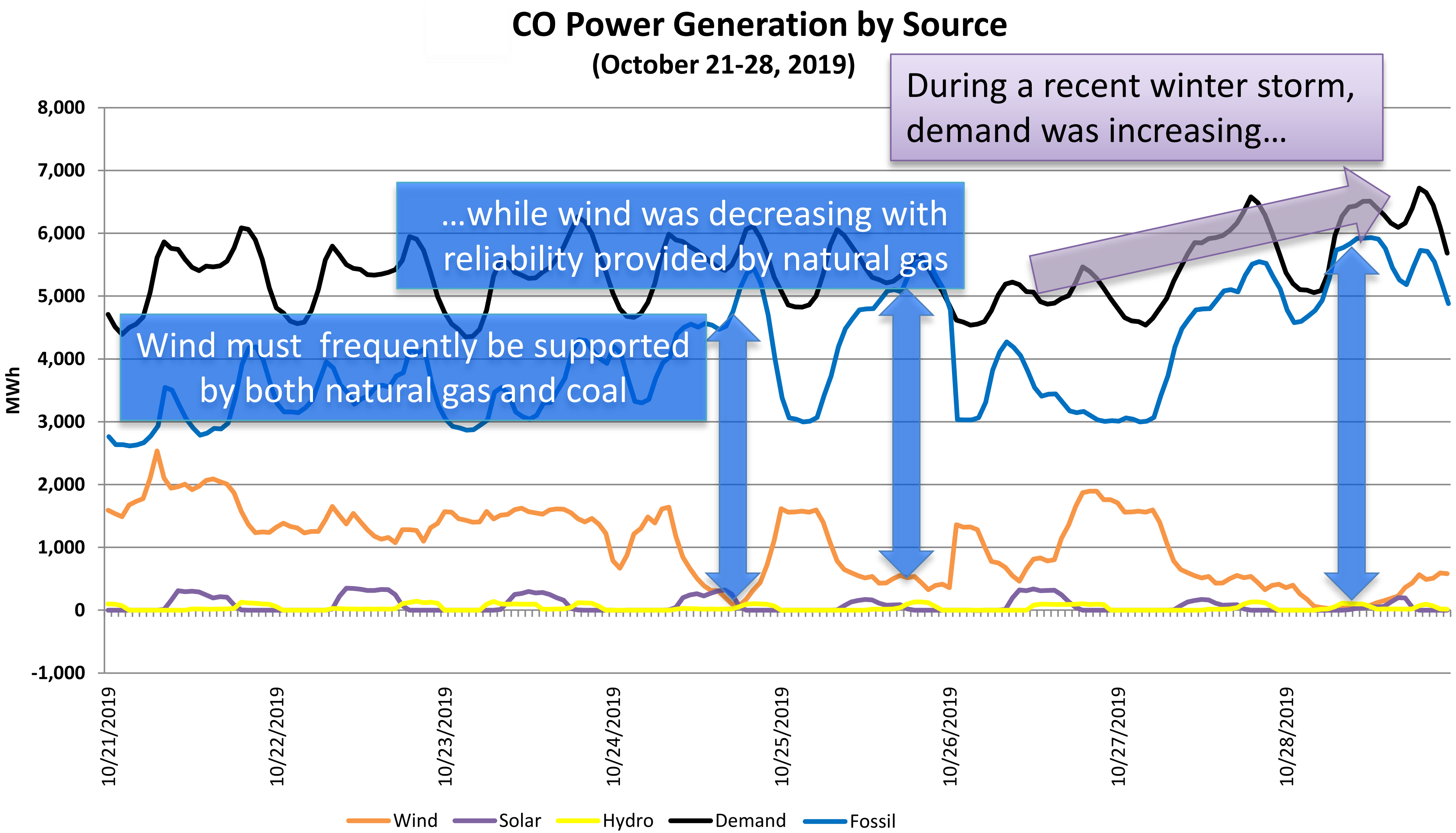
May 5, 2020

Natural Gas Role in the Clean Energy Future

Will W. Brown, PE
Vice President
Kinder Morgan

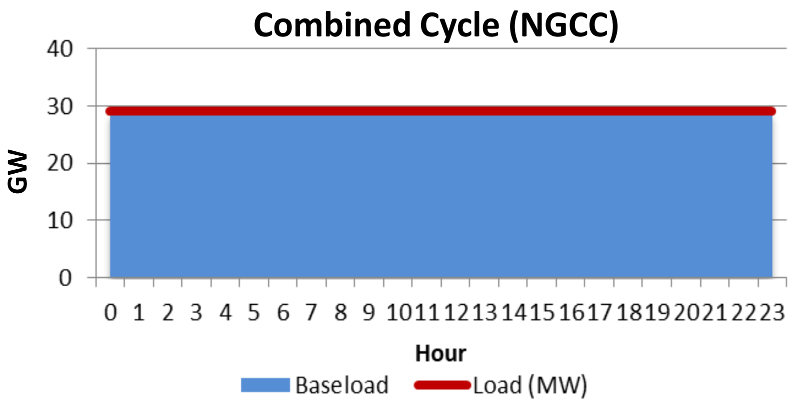
Delivering Energy to Improve Lives and Create a Better World

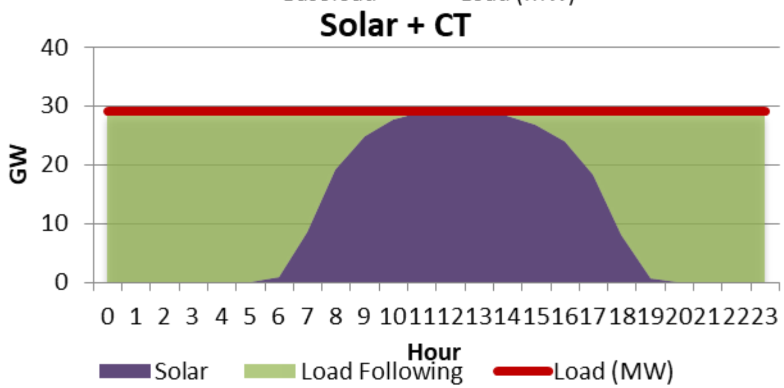
Case Study – Front Range of Colorado

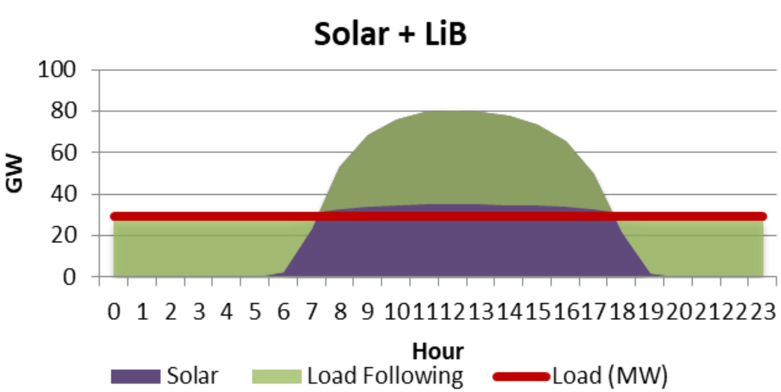


Source: EIA Real-time grid data

GHG Comparison of Generation Sources







	CAPEX[1] ($B)	Scope 1,2[2] (MMT CO_{2e}) Day 1	Scope 3[2] (MMT CO_{2e}) Day 1
Combined Cycle	49	0.26	10
Solar + CT	158	0.34	197
Wind + CT	182	0.27	75
Solar + LiB Grid - Connected	518	0.30	657
Wind + LiB Grid-Connected	325	0.23	141

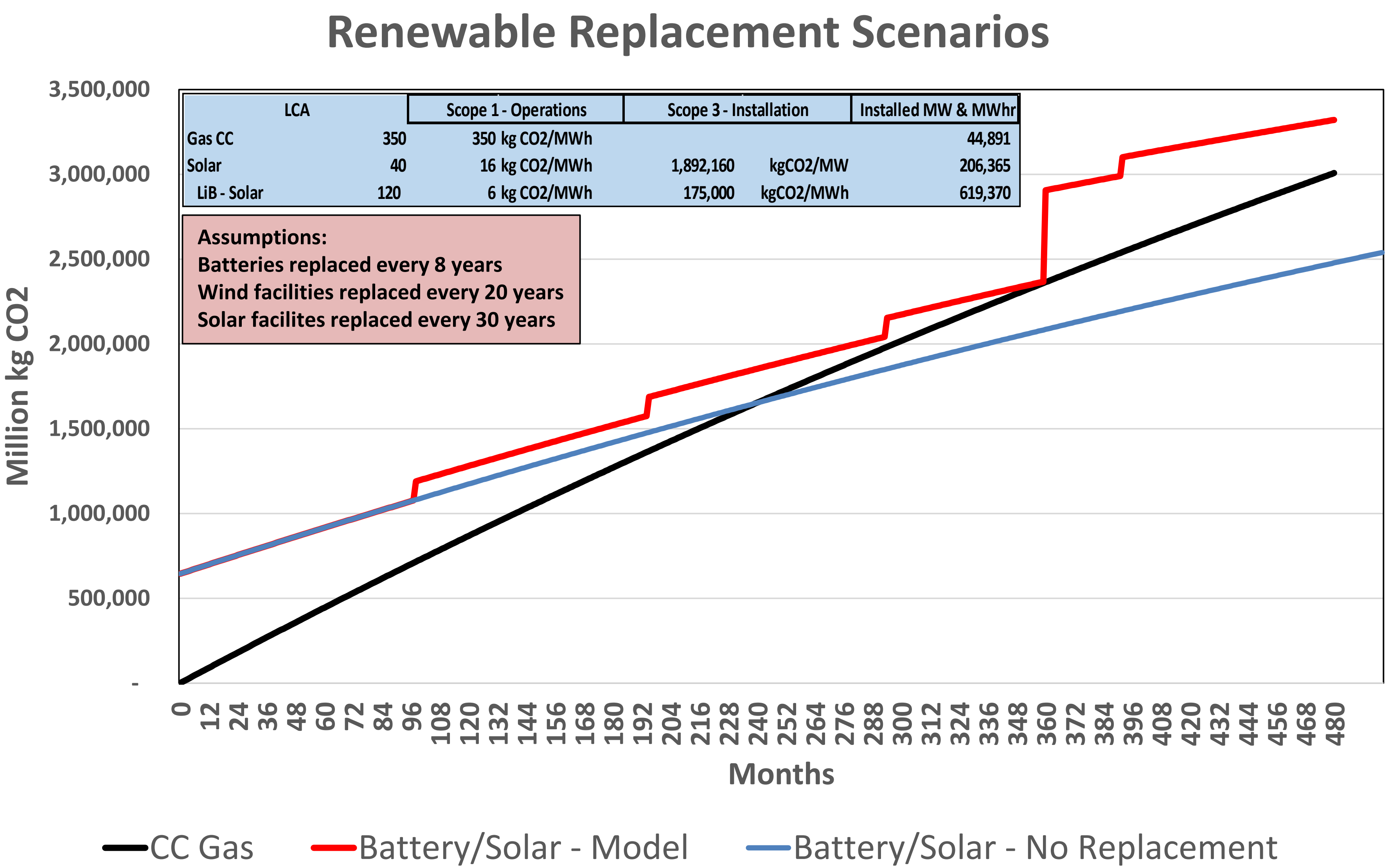
More material inputs (Scope-3 emissions) are created for RE versus the existing fossil fuel infrastructure.

Life-Cycle Analysis will become critical to assess the scope 1-3 emissions of a continuous cycle of build, maintain, replace to keep the RE machine going.

Note: Values reflect empirical seasonal and hourly variation in load and generation and average NERC grid reliability. Source: CAISO.

[1]From LAZARD's Levelized Cost of Energy v12 and Levelized Cost of Storage v4
[2]NREL Life Cycle Greenhouse Gas Emissions from Solor Photovoltaics, NREL Wind LCA Harmonization, IVL The Life Cycle Energy Consumption and GHG from LiB

Emissions Comparison



LCA		Scope 1 - Operations	Scope 3 - Installation		Installed MW & MWhr
Gas CC	350	350 kg CO2/MWh			44,891
Solar	40	16 kg CO2/MWh	1,892,160	kgCO2/MW	206,365
LiB - Solar	120	6 kg CO2/MWh	175,000	kgCO2/MWh	619,370

Summary

- The clean energy future is real and gathering pace through a combination of renewable energy technology advancements and state, national, and global climate change initiatives
- Natural Gas is abundant, energy dense, clean, cheap, efficient, dispatchable = reliable
- Natural gas pipelines facilitate and accelerate the penetration of renewable energy by providing
  - Essential reliability and resiliency
  - Cost effective generation to maintain affordable rates for consumers
- Natural gas and the infrastructure to deliver it also have been the primary source of reductions in GHG emissions and will continue to be a critical part of the clean energy future
- "Planet of the Humans" – Michael Moore YouTube, 3MM Views since Earth Day (4/22/2020)

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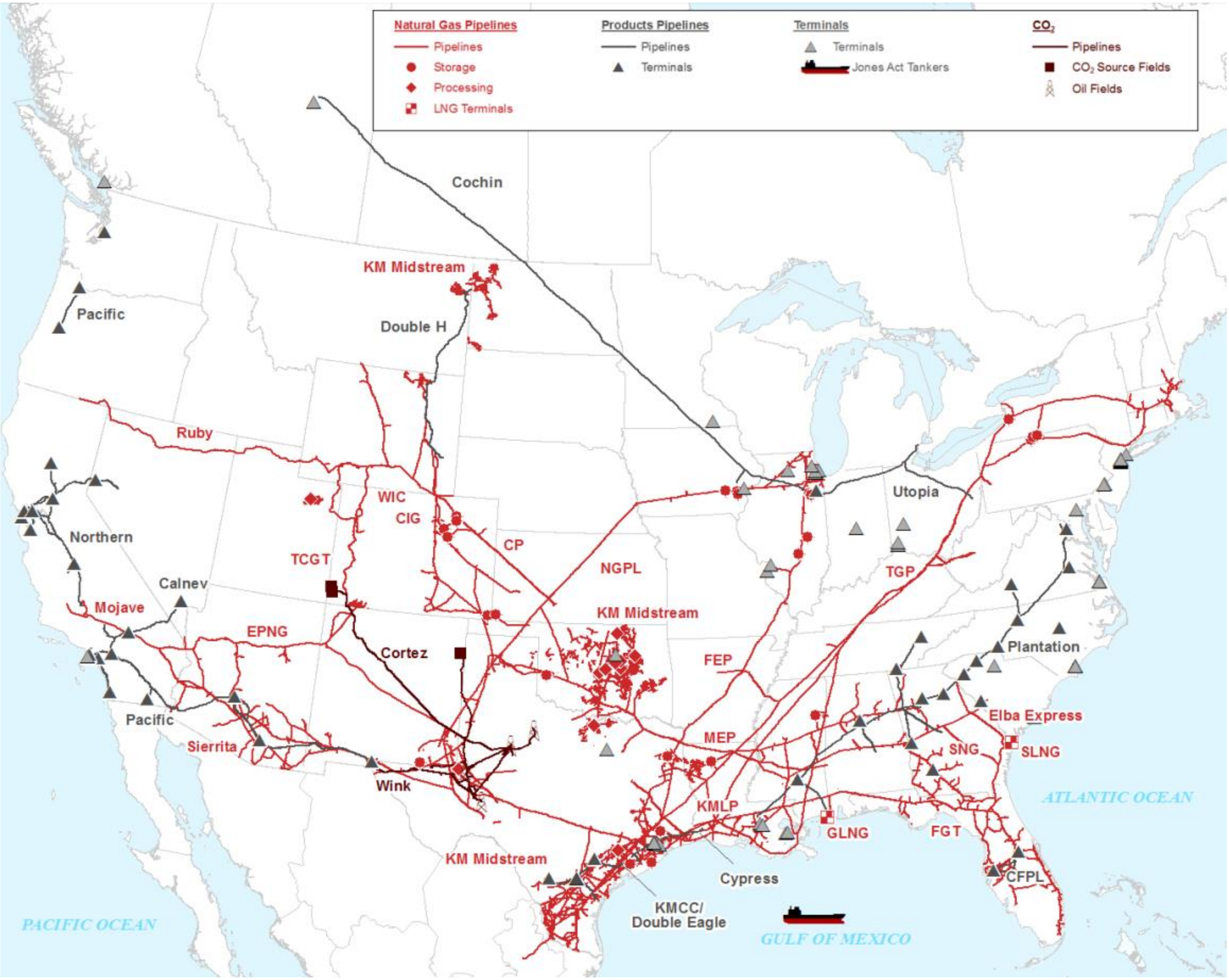
Appendix

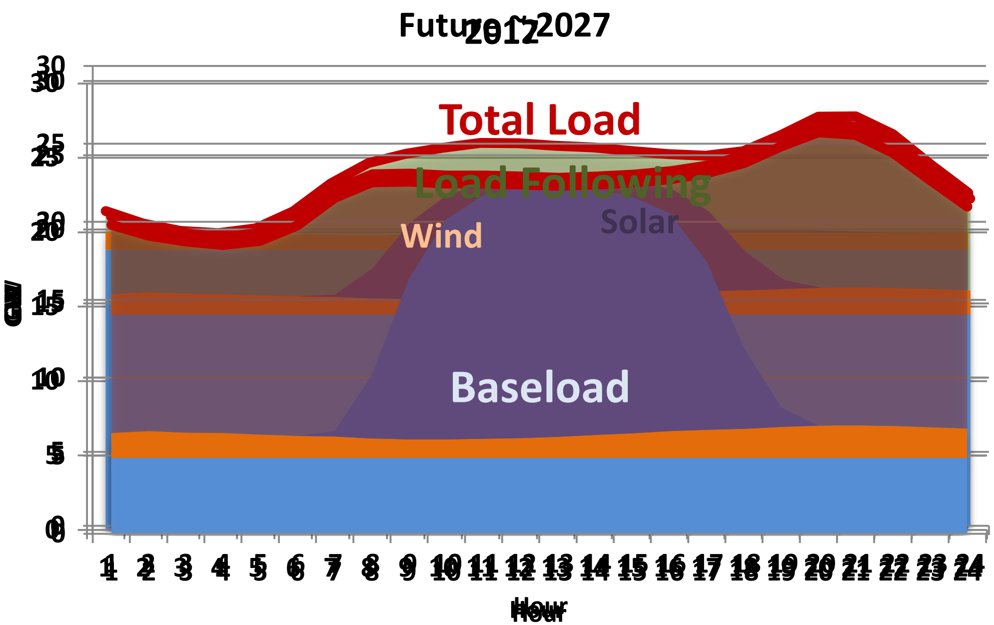
Kinder Morgan Asset Map

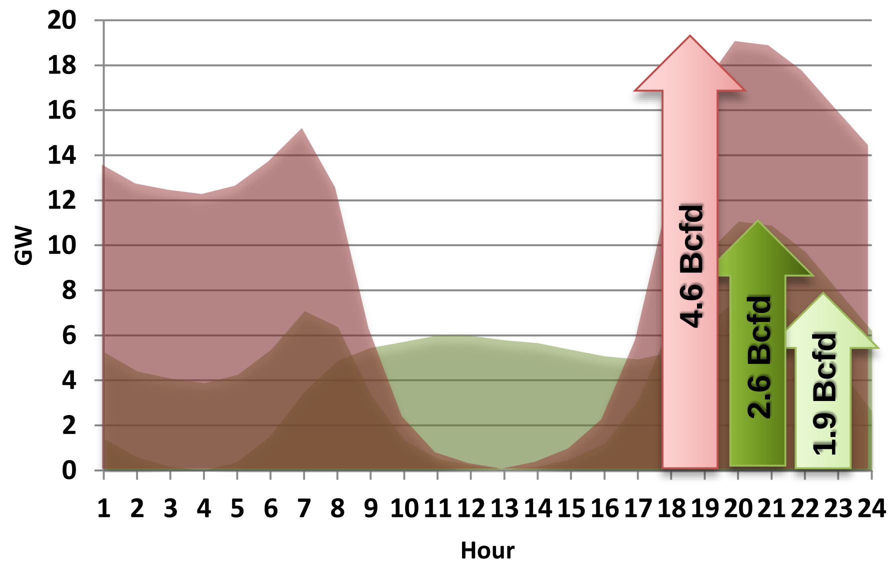
- Largest natural gas network in North America
- Largest independent transporter of petroleum products in North America
- Largest transporter of CO_2 in North America
- Largest independent terminal operator in North America
- Western Pipelines
  - 10 Assets
  - 18,000 Miles
  - 100 BCF



Natural Gas Complements Renewable Growth

As renewable generation increases, pipeline deliverability becomes increasingly important to natural gas-fired generation for load following



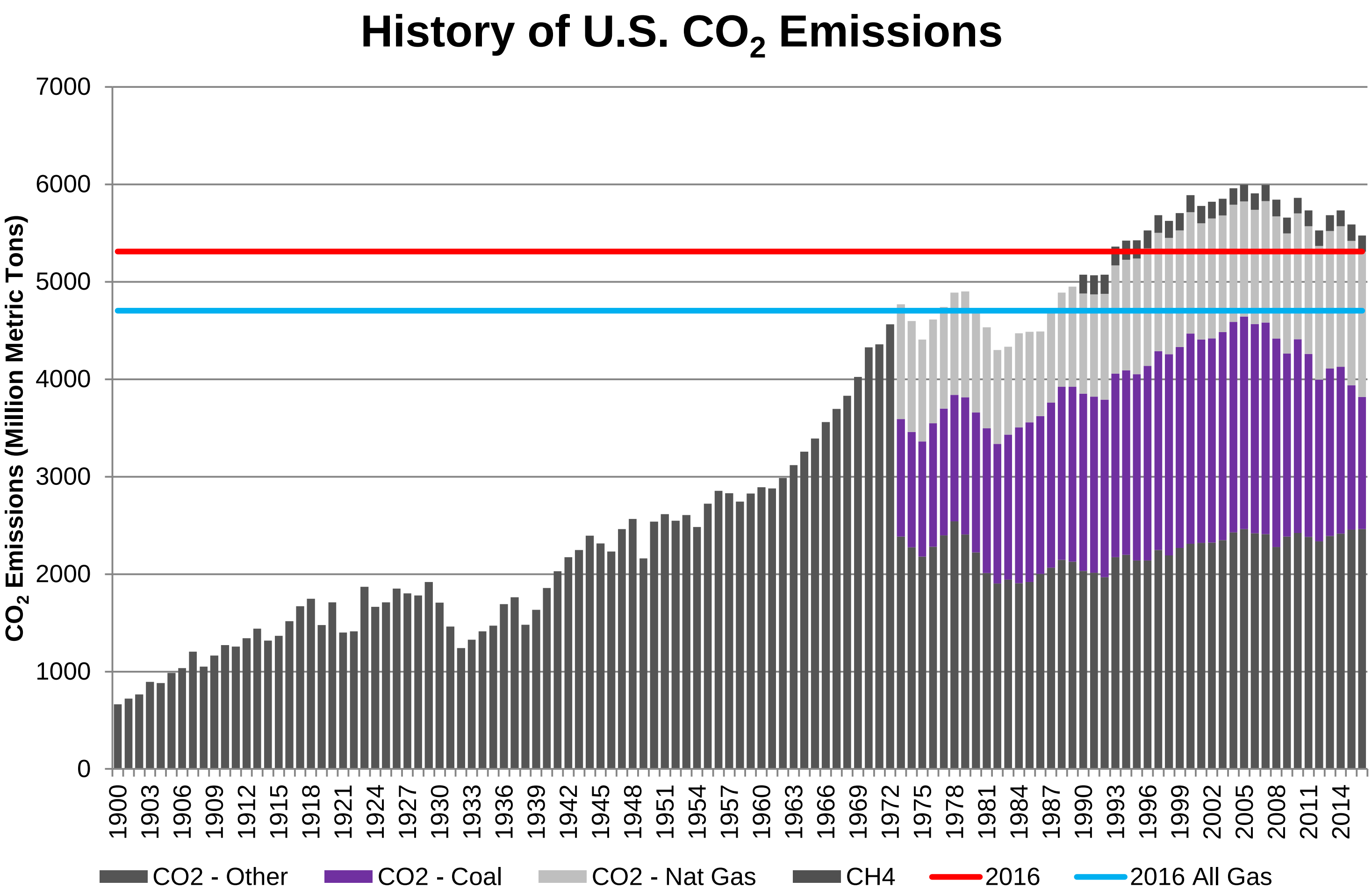


Reaching levels of renewable penetration > 50% requires excess renewable capacity, large transmission builds, AND significant energy storage capacity

Higher deliverability requires more capacity reservation (No-Notice, Hourly Services), more reliance on pipeline linepack, and/or market area storage

Sources: CAISO; KM analysis

U.S. CO_2 Emissions



Greater natural gas fired generation has helped the U.S. reduce CO_2 emissions

Replacing all remaining coal generation with natural gas generation would reduce U.S. CO_2 emissions to pre-1987 levels

Reductions in coal-fired generation have been largely responsible for reductions in CO_2 emissions.

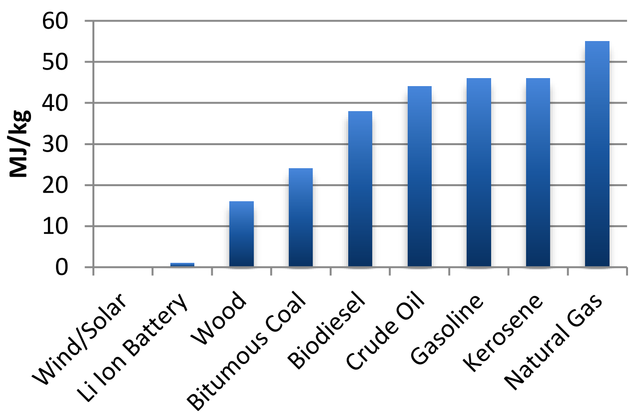
CO_2 emissions grew steadily though 2006 but have been falling as a result of the shale gas revolution and displacement and retirement of coal generation.

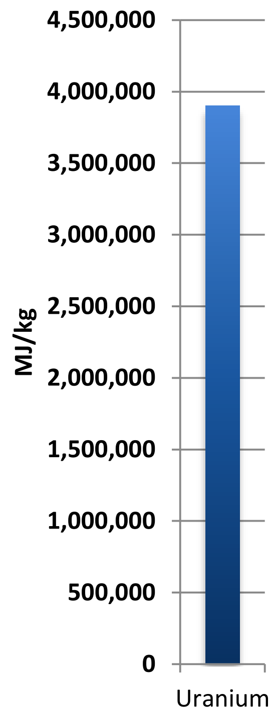
Source: EIA, EPA, Oak Ridge National Laboratory

Comparative Energy Densities

Energy Density

Source	MJ/kg
Wind/Solar	0.00006
Li Ion Battery	1
Wood	16
Bitumous Coal	24
Biodiesel	38
Crude Oil	44
Gasoline	46
Kerosene	46
Natural Gas	55
Uranium	3,900,000





Land Area to Meet 100% of 2018 U.S. Power Generation

Solar + Battery =

Wind + Battery =

Natural Gas =

Note: Land Area for equivalent generation at 99% reliability. Natural gas land area includes power plant + sand production + natural gas wells. Solar and Wind land areas do not include land use for mining, manufacturing, or disposal.

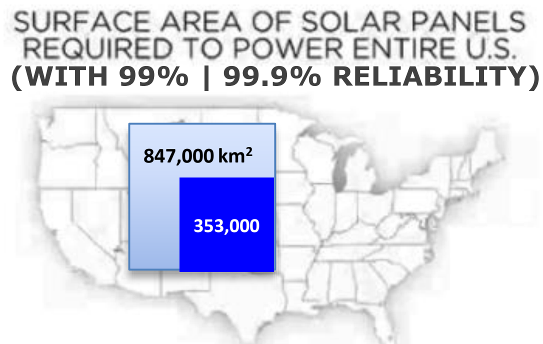
Source: CHBC 2015; NREL 2013b; FCH Jun 2015, EIA, Natural Gas Supply Assoc., NREL

We Need a Bigger Blue Square

2,270 GW capacity
$2.3 Trillion CAPEX[8]
4.0 Billion MT CO_2e[9]

Natural Gas CC:
3,400 km^2
718 GW capacity
$718 Billion CAPEX[8]
1.5 Billion MT CO_2e/year

The Math:	Source
4,171[1] TWh/year	EIA 2018 U.S. Power Generation
476 GW	$\frac{4{,}171\ \text{TWh/yr}}{8{,}760\ \text{hrs/yr}}$
21% Load Factor	NREL PVWatts for N. TX[2]
0.24 GW/km^2	1 kW/m^2 x 24% module efficiency[3]
9,400 km^2	$\frac{476}{0.24 \times 0.21}$



9,880 GW capacity
$9.9 Trillion CAPEX[8]
18 Billion MT CO_2e[9]

23,720 GW capacity
$23.7 Trillion CAPEX[8]
42 Billion MT CO_2e[9]

NOTE: Excludes Energy Storage Cost, CO_2e, and Land Area

The Math:	Source	Factor
14.24 TWh[4]	EIA Peak day U.S. L48 Demand on 8/11/2016	Not used
593 GW	$\frac{14{,}240\ \text{GWh}}{24\ \text{hrs}}$	x 1.25
6.0% | 2.5% Load Factor	L48 load factor at 99% | 99.9% confidence[5] using EIA hourly generation and installed capacity. U.S. L48 avg. solar load factor is 17%[6]	x 3.5 | x 8.4
0.028 GW/km^2	NREL Total Solar Area factor[7]	x 8.57
353,000 km^2 | 847,000 km^2	$\frac{593}{0.06 \cdot 0.028} \Big| \frac{593}{0.025 \cdot 0.028}$	x 38| x 90

[1]EIA 2018 Total Power Generation 4,171 TWh https://www.eia.gov/tools/faqs/faq.php?id=427&t=3
[2]https://pvwatts.nrel.gov/pvwatts.php
[3]Green et al, Solar Cell Efficiency Tables (Version 45), Table 2, GaAs (thin film)
[4]EIA Real Time Grid

[5]NERC 2018 grid reliability was 99.92%
[6]Load factor from NREL's PVWatts is 17.5% in center of U.S. (Kansas)
[7]NREL "Land Use for Solar Power Plants in the United States" page 17 shows 8.9 Acres/MW
[8] Lazard's Levelized Cost of Energy Analysis Version 13.0, using avg. CAPEX value
[9]40 kg/CO2e/MWh per NREL Life Cycle Greenhouse Gas Emissions for Solar Photovoltaics

Life Cycle Assessment of GHG Emissions

Total Emissions Footprint = **SCOPE 1 'Direct'**: Direct emissions from "Usage" of the owned or controlled sources + **SCOPE 2 'Indirect'**: Indirect emissions from the generation of the energy sources + **SCOPE 3 'Up/Downstream Effects'**: All indirect emissions that occur in the value chain (upstream/downstream) of the sources

	SCOPE 1	SCOPE 2	SCOPE 3
Gas (CC/CT)	✓	✓	✓
Coal	✓	✓	✓
Nuke	No Emissions	Water Vapor? ✓	✓
RE (Wind/Solar)	No Emissions	✓	✓
Energy Storage (LIB)	No Emissions	✓ **GHG Emissions from re-charging diminishes over time** → ✓	✓

Power vs. Natural Gas Transmission

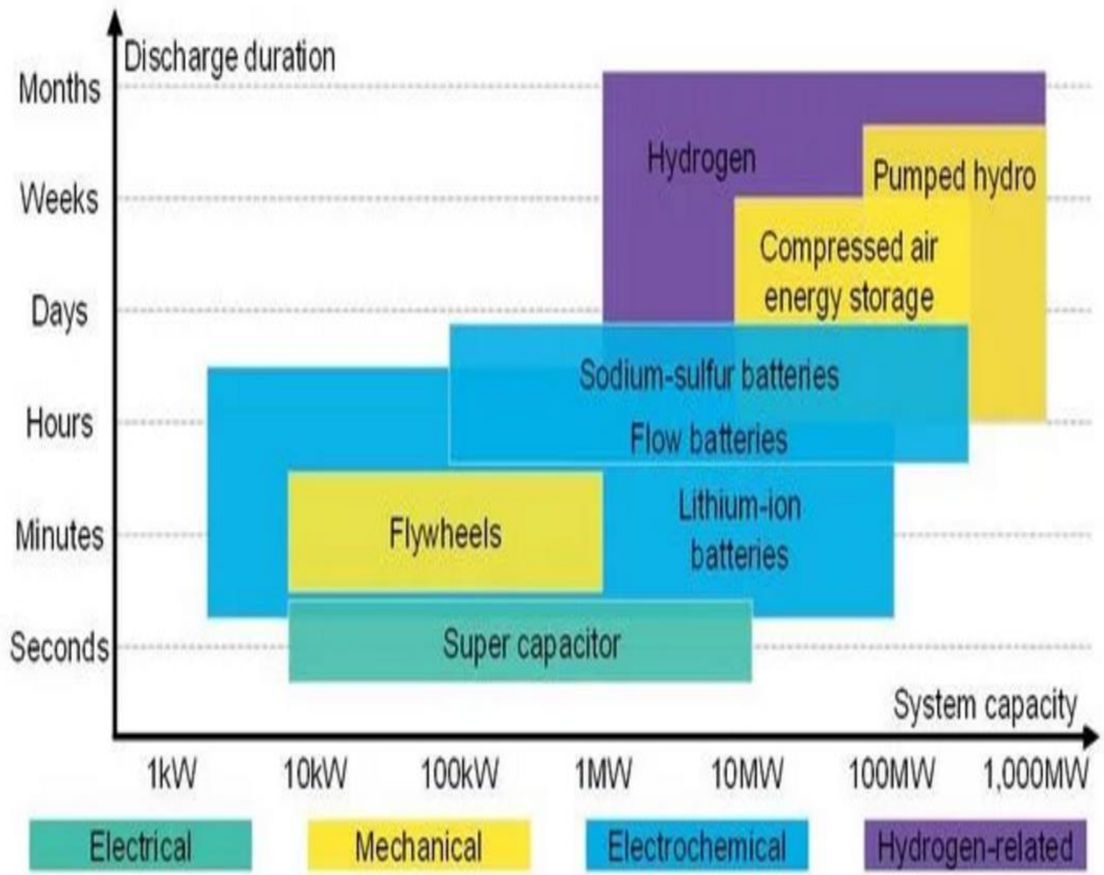
Conduit	Capacity (MW)	1 Bcfd Pipeline Equiv. Factor	Pipeline Equiv. Cost ($MM/mile)	Pipeline Equiv. Line-Loss (%/100 miles)
1 Bcfd gas pipeline	4,750	x1.00	$3.9	0.3%
600 kV HVDC	3,500	x1.36	$7.2	0.7%
765 kV HVAC	2,300	x2.07	$7.1	1.7%
500 kV HVAC	900	x5.28	$15.6	6.9%
345 kV HVAC (double)	750	x6.33	$13.2	26.6%

Natural gas pipelines are more efficient and more cost-effective than power transmission

Growth in renewables (typically located far away from major load centers) and electrification requires significant investment in new power transmission

Sources: ICF International Transmission assessment for EIA June, 2018; AEP Transmission Facts; KM analysis

Size and Discharge Duration by Energy Storage Technology



Source: Bloomberg New Energy Finance. Note: system capacities and discharge durations are based on general use, rather than technical limitations.

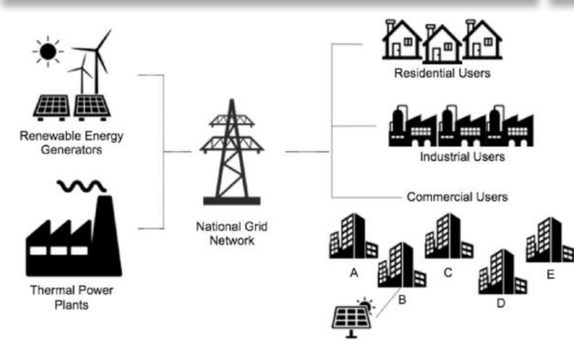
Cost are improving for battery technologies to penetrate the area of bulk power management applications for utility-scale operations, such as renewable backstopping and firming.

Lithium Ion battery technologies are currently suited for smaller duration such as, power smoothing (i.e VAR and frequency support), power quality, and overall grid support

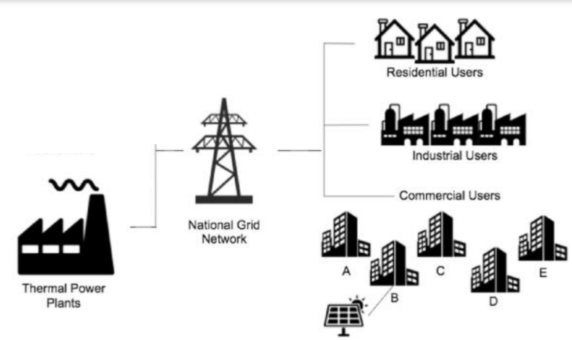
Let’s Compare Apples to Apples

“Current” Narrative	“New” Narrative	Benefits / Differences
Capacity	Deliverability	Grid Reliability & Resiliency
Per Unit Cost (LCOE)	**Total System Cost**	LCOE ≠ Total Cost of Equivalent Performance
“Tailpipe” Emissions (Scope 1)	**Total System Emissions**	It’s **TOTAL EMISSIONS** that matter
	Brownfield vs. Greenfield	Scope 1 vs. Scope 1 - 3
	A full LifeCycle Assessment (LCA)	Although imperfect, an LCA per MWh of load served must be performed in order to achieve consistent comparison of investment alternatives

VS.



VS.



The Industry needs to influence policy makers at all levels (Federal/State/Local) to embrace new narrative when discussing clean energy and climate related goals.