

Battery Energy Storage Technology – The Nexus of all Energy



Prepared for: IEEE Central Texas Consultants Network 05/18/2021
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Disclaimer

The view and opinions expressed herein are those of the author (Thomas Ortman) and do not reflect the official policy or position of Voltabox of Texas, Inc.

Battery Energy Storage Systems – BESS (RESS / ESS) – The Nexus of all Energy

or...

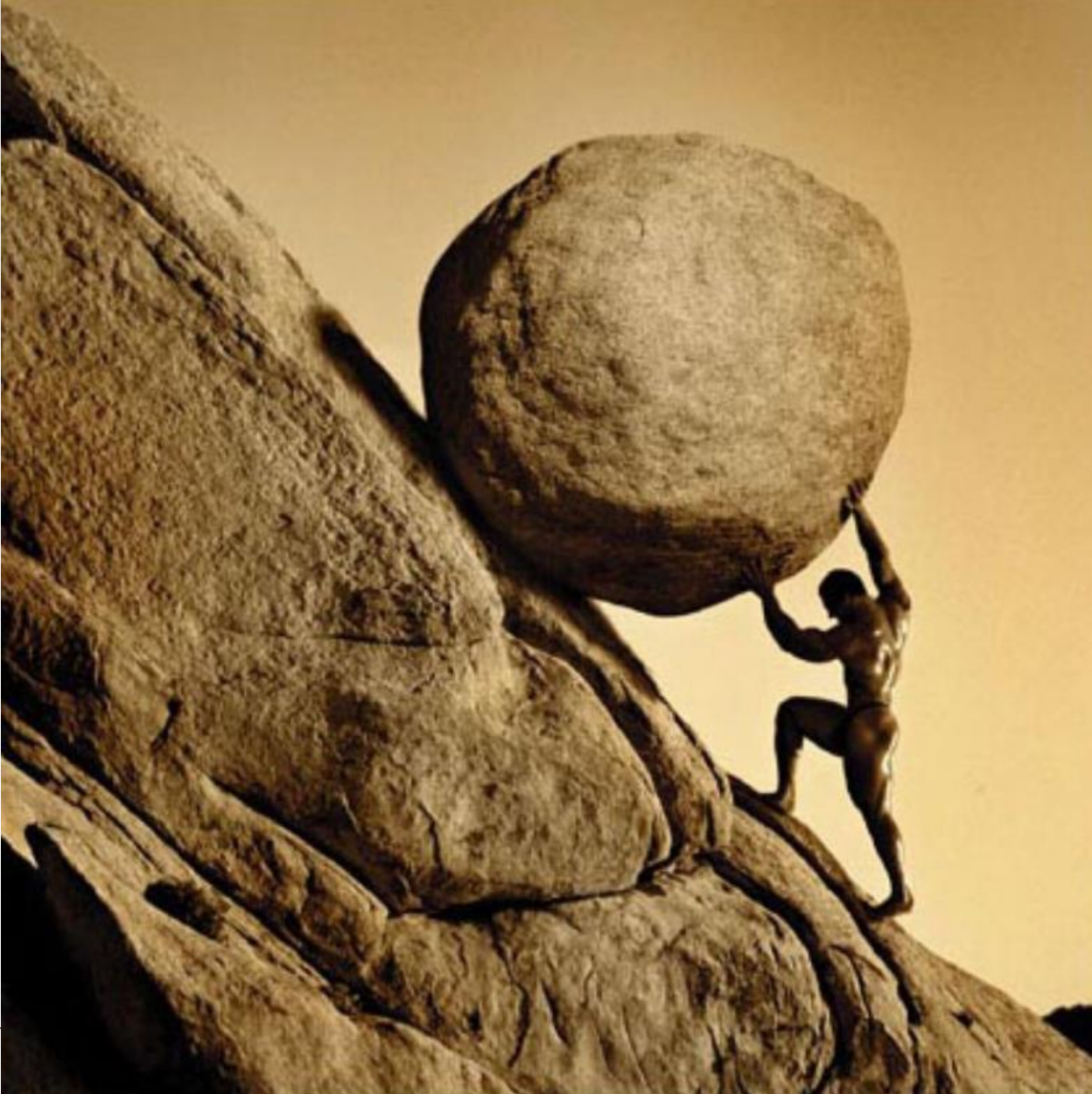
...why the coal, oil, gas, automotive, trucking, taxi, rail, shipping, utility industries are about to become unrecognizable,

...and why every corner gas station, oil change joint, transmission shop, auto mechanic business, convenience store, grocery store, hotel, mall, restaurant, electrician, job seeker, Uber driver and investor should really pay attention.

aka...

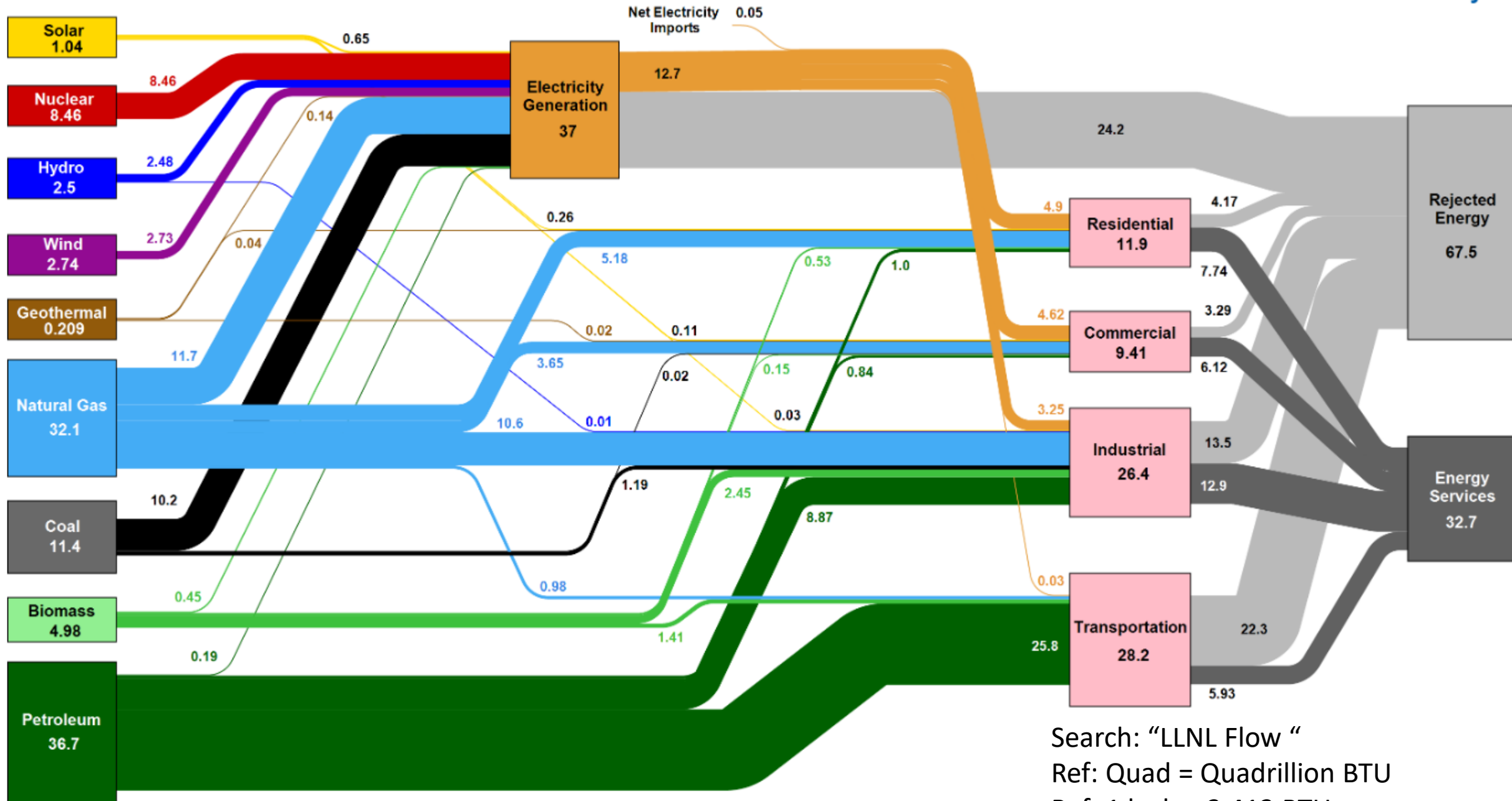
...the biggest business opportunity of our lifetime

BESS - THE NEXUS OF ALL ENERGY



Source: © erhui1979 / DigitalVision Vectors / GettyImages

Estimated U.S. Energy Consumption in 2019: 100.2 Quads



Search: "LLNL Flow"
 Ref: Quad = Quadrillion BTU
 Ref: 1 kwh = 3,412 BTU

Storage <> Energy <> Storage > Energy

Energy (Incumbent > Dispatchable)

- Biomass: Solar Energy > Storage > Useable Energy (Renewable)
- Coal: Solar Energy > Storage > Useable Energy (Fossil)
- Oil: Solar Energy > Storage > Useable Energy (Fossil)
- Natural Gas: Solar Energy > Storage > Useable Energy (Fossil)
- Hydro: Solar Energy > Storage > Useable Energy (Renewable)
- Nuclear: Solar Energy > Storage > Useable Energy
- Solar Thermal: Solar Energy > Storage > Useable Energy (Renewable)

Energy (Incumbent > NOT Dispatchable)

- Wind: Solar Energy > Useable Energy (Renewable)
- Solar PV: Solar Energy > Useable Energy (Renewable)

Storage <> Energy <> Storage > Energy

Storage

- Pumped Hydro: Energy > Storage > Useable Energy
- Kinetic: Energy > Storage > Useable Energy
- Thermal: Energy > Storage > Useable Energy
- CAES: Energy > Storage > Useable Energy
- BESS: Energy > Storage > Useable Energy
- Hydrogen: Energy > Storage > Useable Energy
- Supercapacitors: Energy > Storage > Useable Energy
- Geothermal: Storage > Useable Energy

TODAY! Energy <> Storage > Energy

From this...

Energy (Incumbent > Dispatchable)

Coal, Gas, etc.: Solar Energy > Storage > Useable Energy
(Fossil)

To this...

Energy (Incumbent > NOW Dispatchable)

- Wind: Solar Energy > Storage > Useable Energy (Renewable)
- Solar PV: Solar Energy : **Storage >** Useable Energy (Renewable)

BESS - THE NEXUS OF ALL ENERGY...the future of coal?...economics!



Feature image credit: Wikimedia

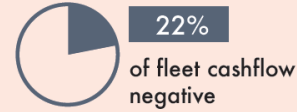
BESS - THE NEXUS OF ALL ENERGY

PROFITABILITY OF COAL POWER IN THE UNITED STATES

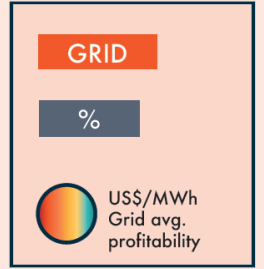
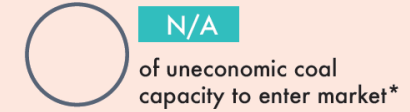
IN THE UNITED STATES, ON AVERAGE:



254 GW Total operating capacity



N/A Planned + under construction capacity



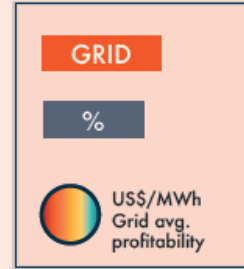
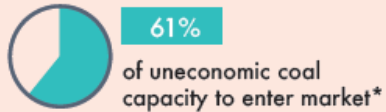
IN CHINA, ON AVERAGE:



982 GW Total operating capacity



206 GW Planned + under construction capacity



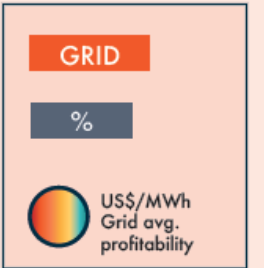
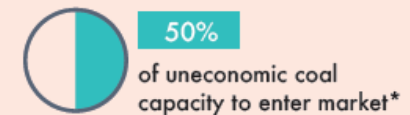
IN EUROPE, ON AVERAGE:



149 GW Total operating capacity

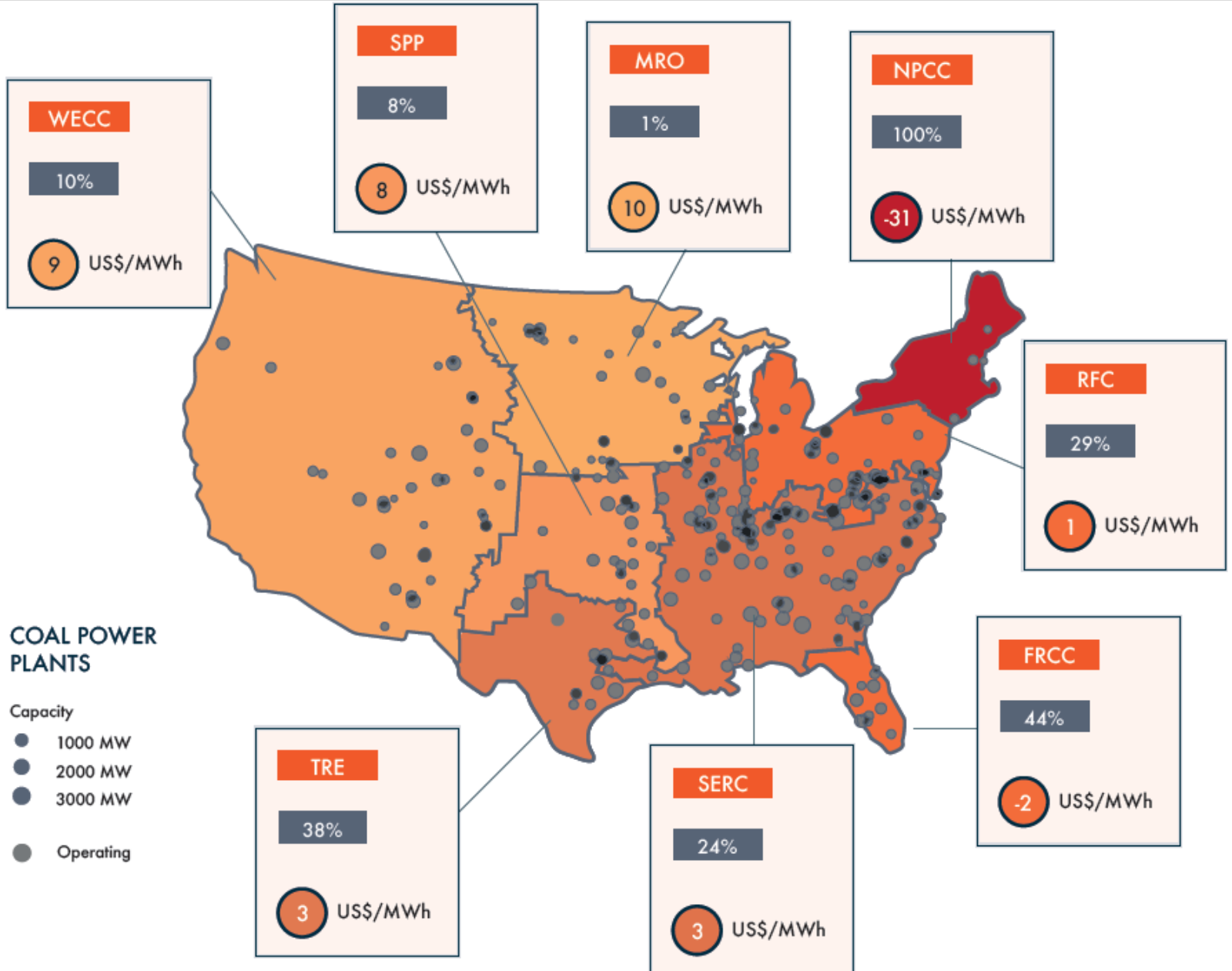


8 GW Planned + under construction capacity



BESS - THE NEXUS OF ALL ENERGY

➤ THE PROFITABILITY OF COAL IN THE UNITED STATES



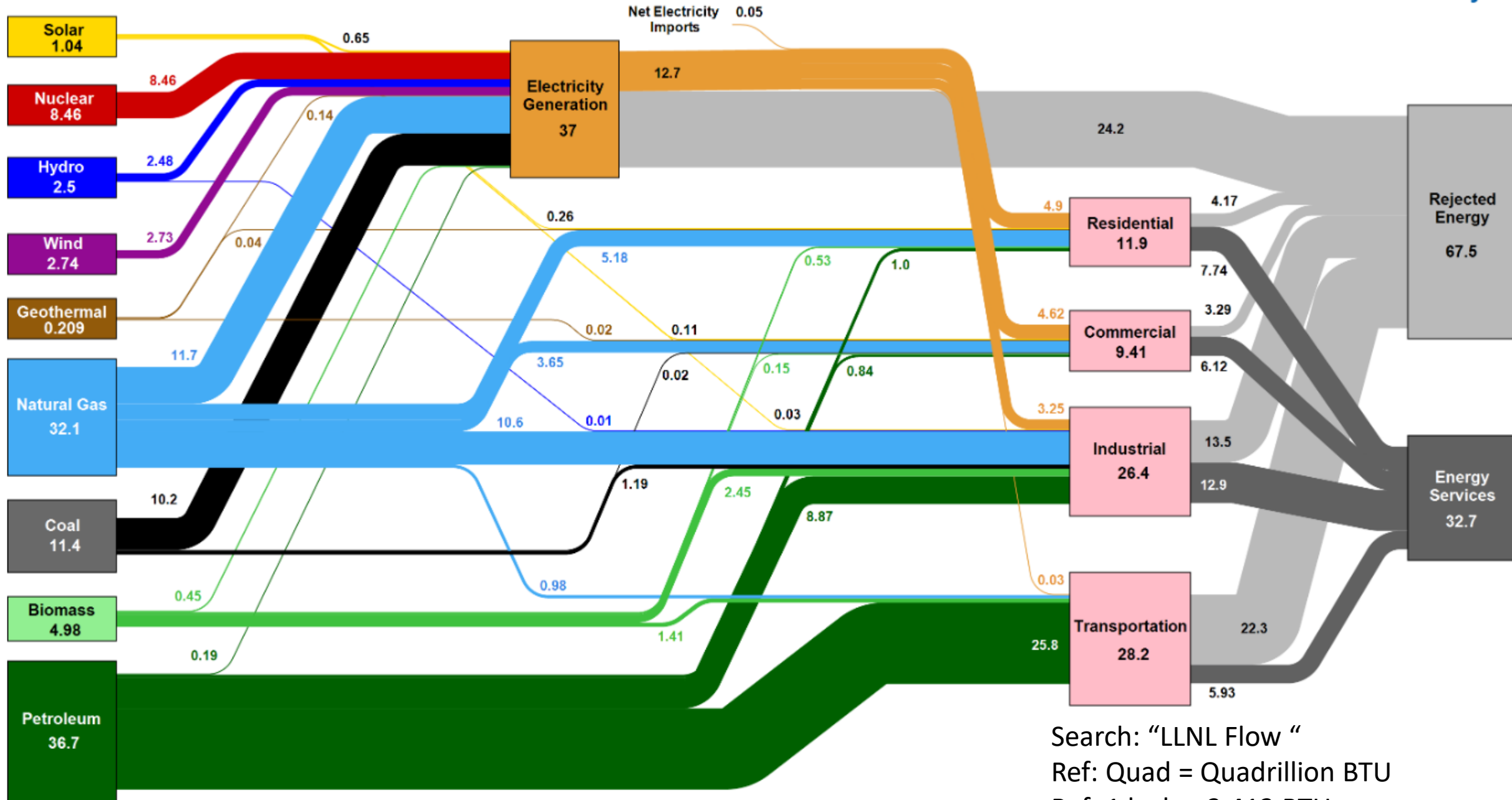
Source: Carbon Tracker _ Coal Profitability Maps_Profitability_5_NE

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Coal Plant Closures

Unit Name	Closure Type	Summer Capacity (MW)	Initial Operation Date	Date of Closure
GIBBONS CREEK	Indefinite Mothball	470	3/15/1983	6/1/2019*
J T DEELY Unit 1	Indefinite Mothball	420	8/8/1977	12/31/2018
J T DEELY Unit 2	Indefinite Mothball	420	8/1/1978	12/31/2018
BIG BROWN Unit 1	Retired	606	12/23/1971	2/12/2018
BIG BROWN Unit 2	Retired	602	12/6/1972	2/12/2018
SANDOW Unit 4	Retired	600	5/15/1981	1/11/2018
SANDOW Unit 5	Retired	600	1/6/2010	1/11/2018
MONTICELLO Unit 1	Retired	535	12/23/1974	1/4/2018
MONTICELLO Unit 2	Retired	535	12/8/1975	1/4/2018
MONTICELLO Unit 3	Retired	795	8/1/1978	1/4/2018

Estimated U.S. Energy Consumption in 2019: 100.2 Quads



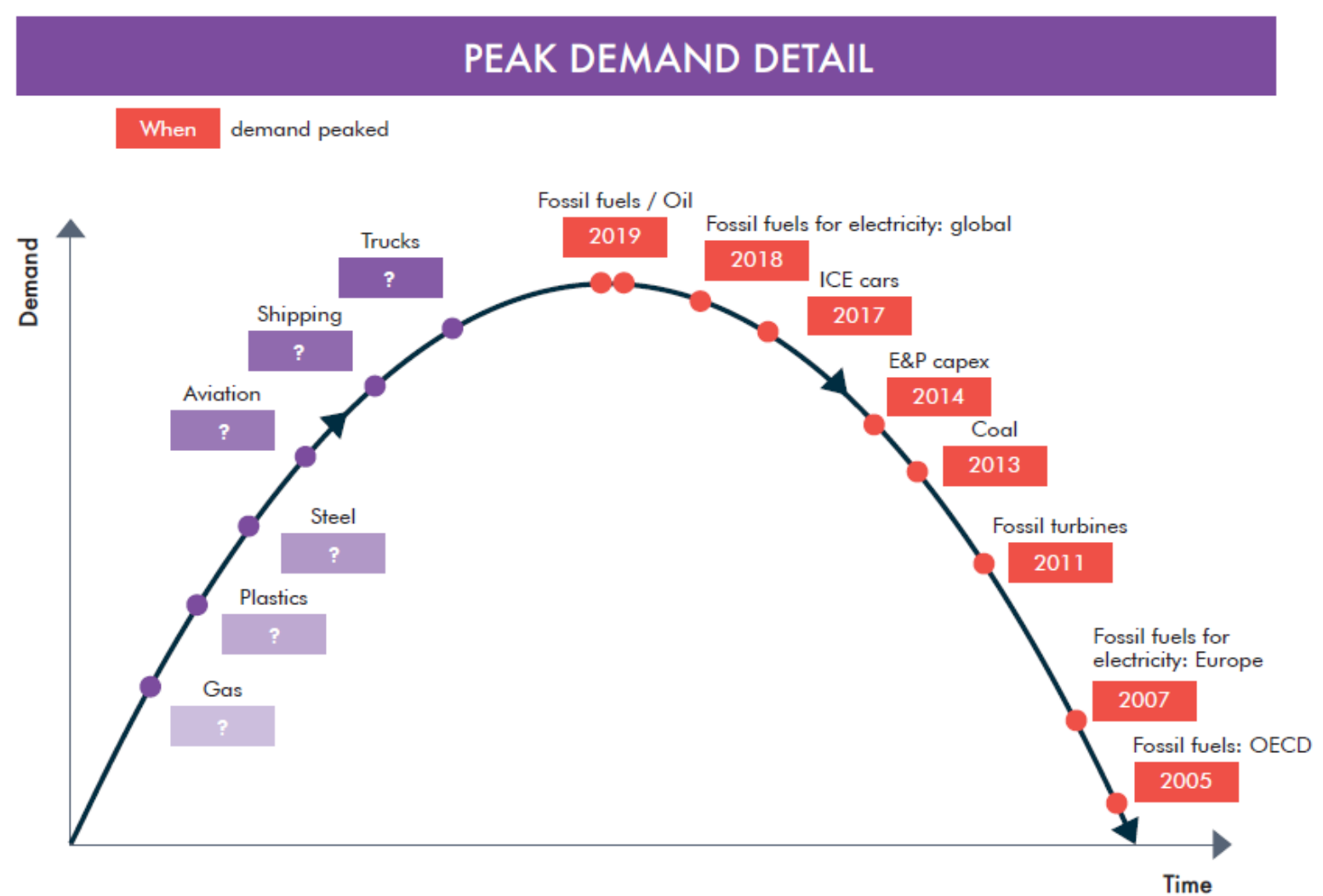
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BESS - THE NEXUS OF ALL ENERGY...the sunset of oil... as we know it?



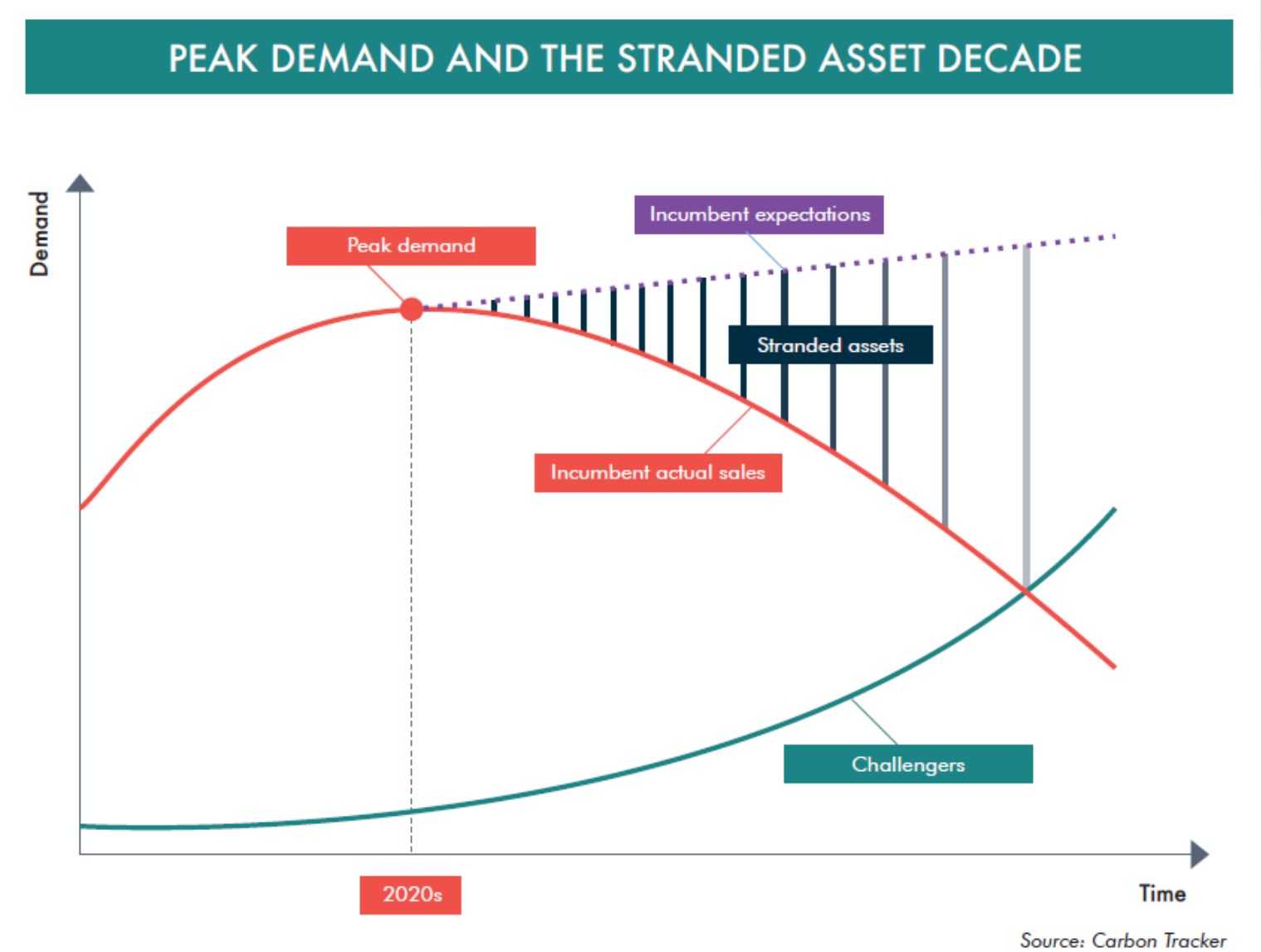
SOURCE: New York Times

BESS - THE NEXUS OF ALL ENERGY



SOURCE: Carbon Tracker _ Fossil Fuel System Decline_and_Fall_Infographics_CTI

BESS - THE NEXUS OF ALL ENERGY



Source: Carbon Tracker

SOURCE: Carbon Tracker _ Fossil Fuel System Decline_and_Fall_Infographics_CTI



BESS - THE NEXUS OF ALL ENERGY

France's Total SE acknowledged last month when it took an \$8 billion write-down on carbon-heavy assets. SOURCE: Bloomberg

BP, said it expected to write down roughly \$17.5 billion worth of assets. SOURCE: Fortune

Shell's \$22 billion Q2 write-down is just the tip of the iceberg for fossil fuels. SOURCE: Fortune

In the first quarter, as the crisis was only beginning to take hold, shale companies alone wrote off \$38 billion in assets. SOURCE: Fortune

... Deloitte predicting that write-downs could hit at least \$300 billion beginning in the second quarter.. SOURCE: Fortune

BESS - THE NEXUS OF ALL ENERGY

Oil Companies Wonder If It's Worth Looking for Oil Anymore – Source: Bloomberg Green

BP Plc said on Aug. 4 that it would no longer do any exploration in new countries. Source: Bloomberg

BP said in June it would evaluate its portfolio of discoveries and leave some undeveloped.

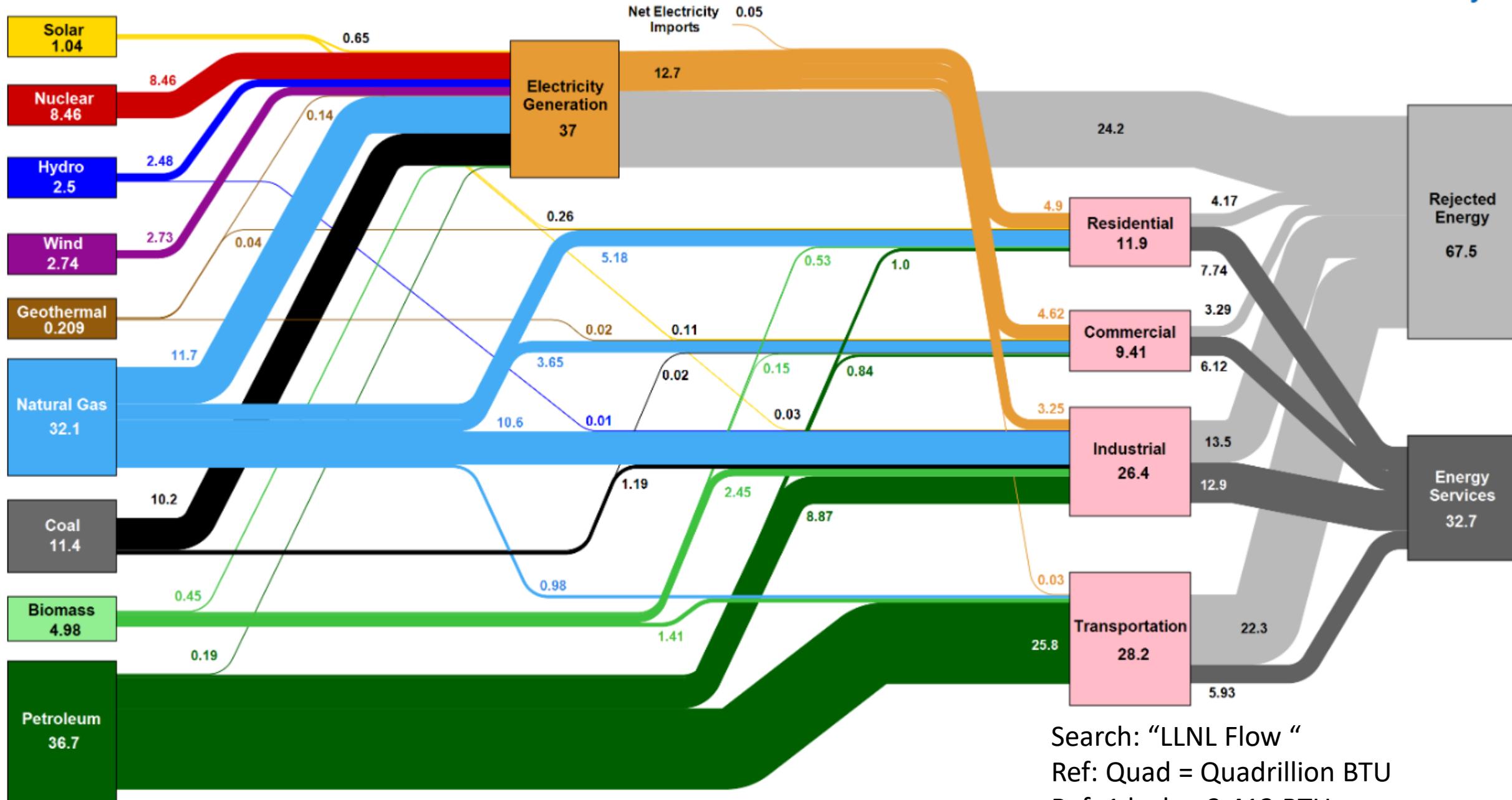
**Canadian oil-sands projects such as the expansion of the Sunrise development in Alberta are also in doubt.
SOURCE: Bloomberg**

No new oil-sands projects fit in a world compliant with the Paris climate accord, according to Carbon Tracker. SOURCE: Bloomberg

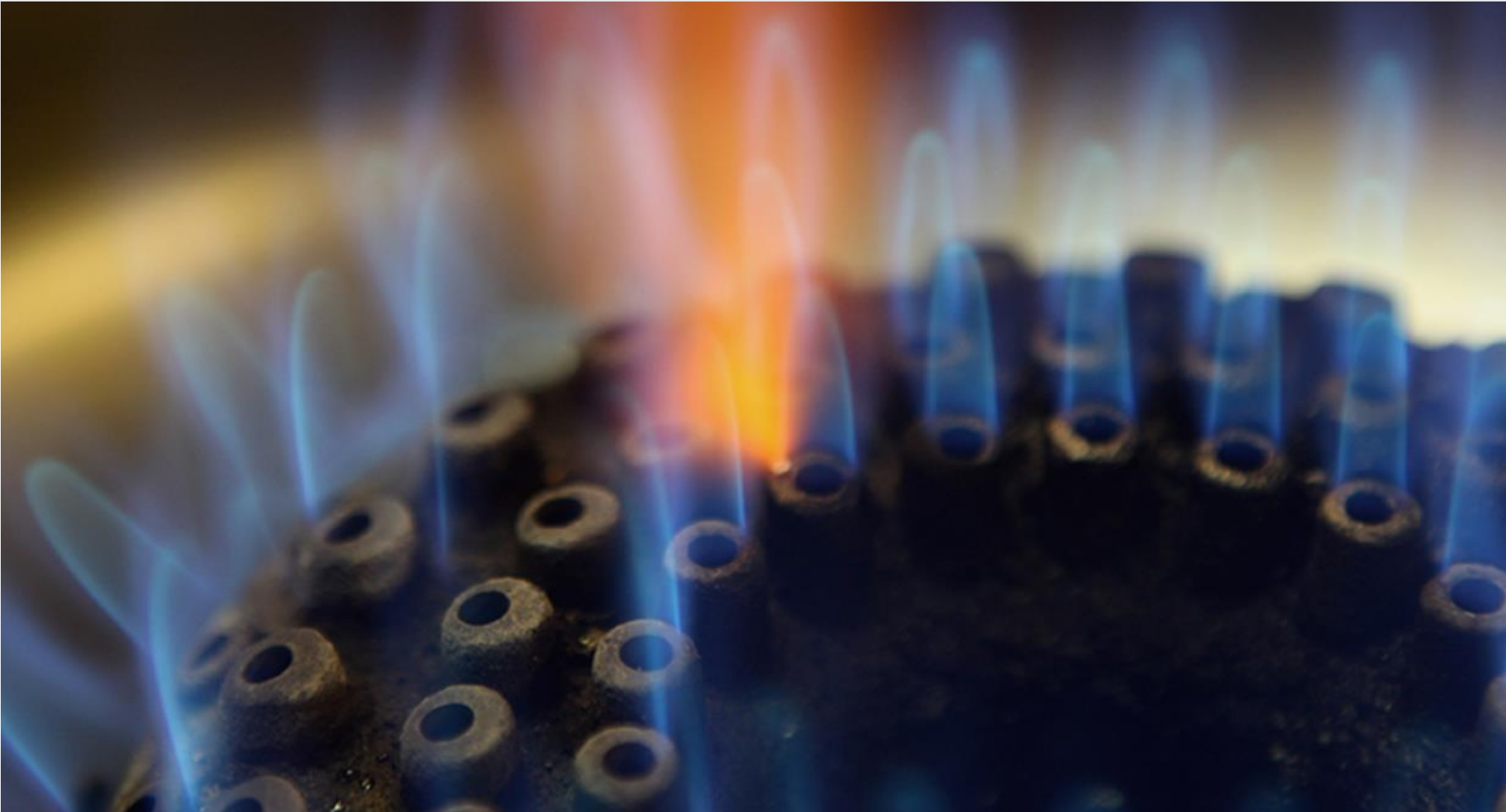
Chesapeake joins more than 200 other bankrupt U.S. shale producers. SOURCE: Worldoil.com

From International Oil Company to Integrated Energy Company: BP sets out strategy for decade of delivery towards net zero ambition. SOURCE: BP.Com

Estimated U.S. Energy Consumption in 2019: 100.2 Quads



BESS - THE NEXUS OF ALL ENERGY...what's next for natural gas?




BESS - THE NEXUS OF ALL ENERGY

Fearing for Its Future, a Big Utility Pushes 'Renewable Gas,' Urges Cities to Reject Electrification

The utility's plan would mix a small amount of biogas with its main product—natural gas—to keep its pipelines running in a state that's aiming for zero emissions.



By Phil McKenna 
November 13, 2019

A Furious Industry Backlash Greeted Moves by California Cities to Ban Natural Gas in New Construction

Gas bans and restrictions, and the industry pushback, is part of a battle on many fronts over the future of natural gas in homes and businesses.



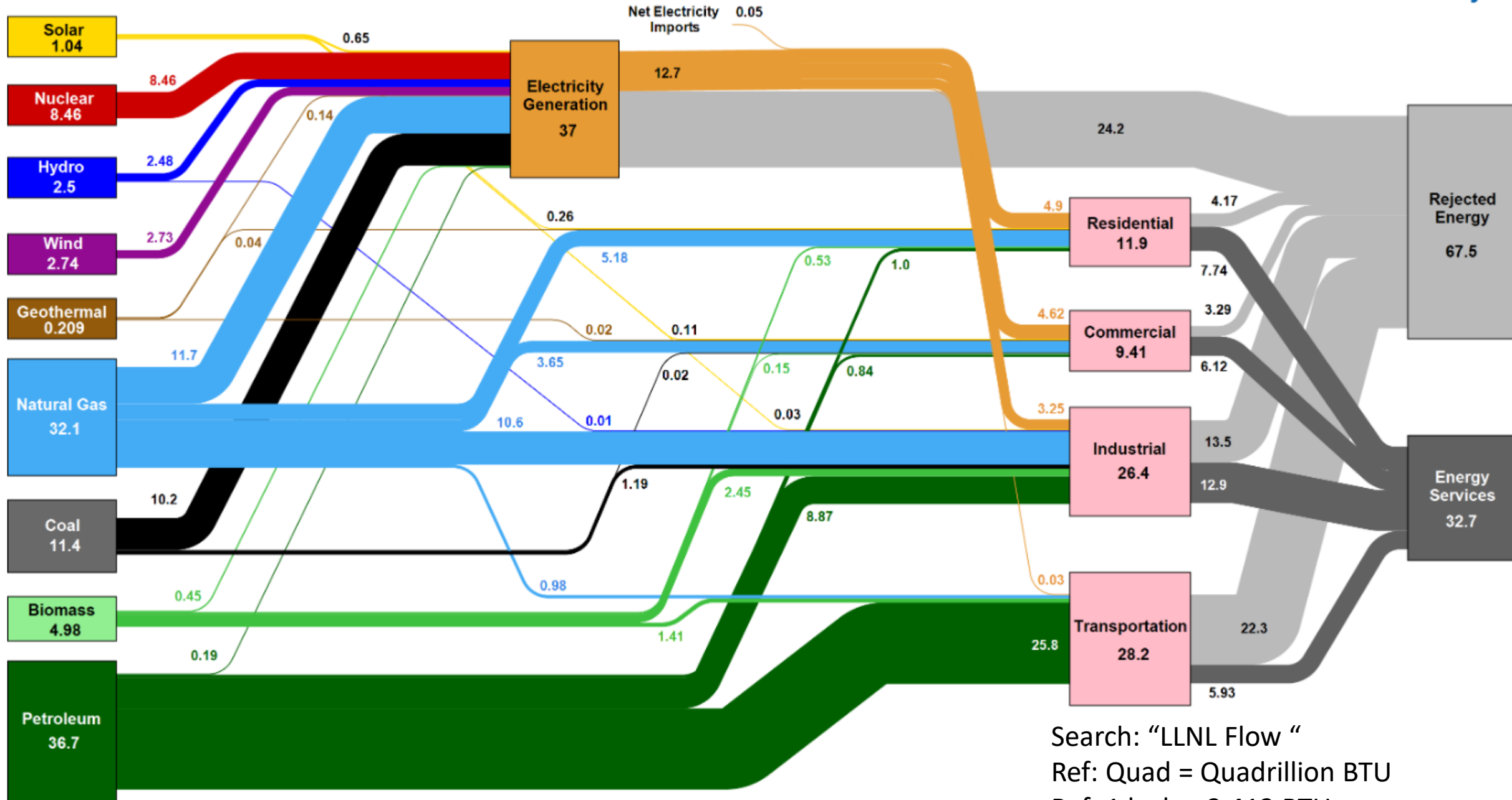
By Dan Gearino 
March 5, 2021

Texas Moves to Kill Gas Bans Proposed by Austin, Others

By [Mark Chediak](#)

March 30, 2021, 2:37 PM CDT *Updated on March 30, 2021, 4:59 PM CDT*

Estimated U.S. Energy Consumption in 2019: 100.2 Quads



Search: "LLNL Flow"
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BESS - THE NEXUS OF ALL ENERGY – THE FUTURE



SOURCE: Dreamstime, SOURCE: Shutterstock

BESS - THE NEXUS OF ALL ENERGY

➤ Theodore Paul Wright

- Chief Engineer of the Curtiss-Wright Corporation
- 1936 Paper “Factors Affecting the Costs of Airplanes.”
- Now known as “Wright’s Law”, or *experience curve effects* and states simply that ...“*we learn by doing*”. (Learning Rate)
- “...the cost of each unit produced decreases as a function of the cumulative number of units produced”.
- Each Doubling of production yields at 10-15% improvement in efficiency (Realized as cost reductions or greater profits)



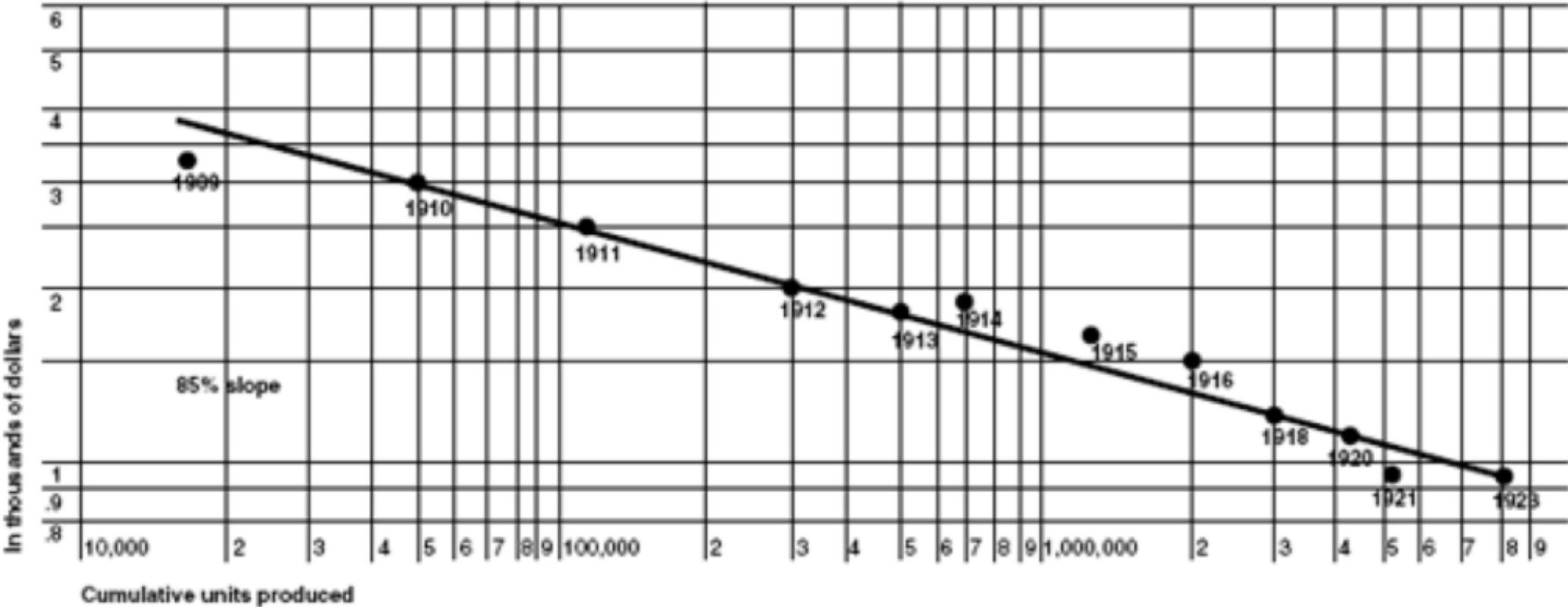
Wright’s Law Formula

Y = cumulative average time (or cost) per unit
X = cumulative number of units produced
a = time (or cost) required to produce 1st unit
b = slope of the function

$$Y = aX^b$$

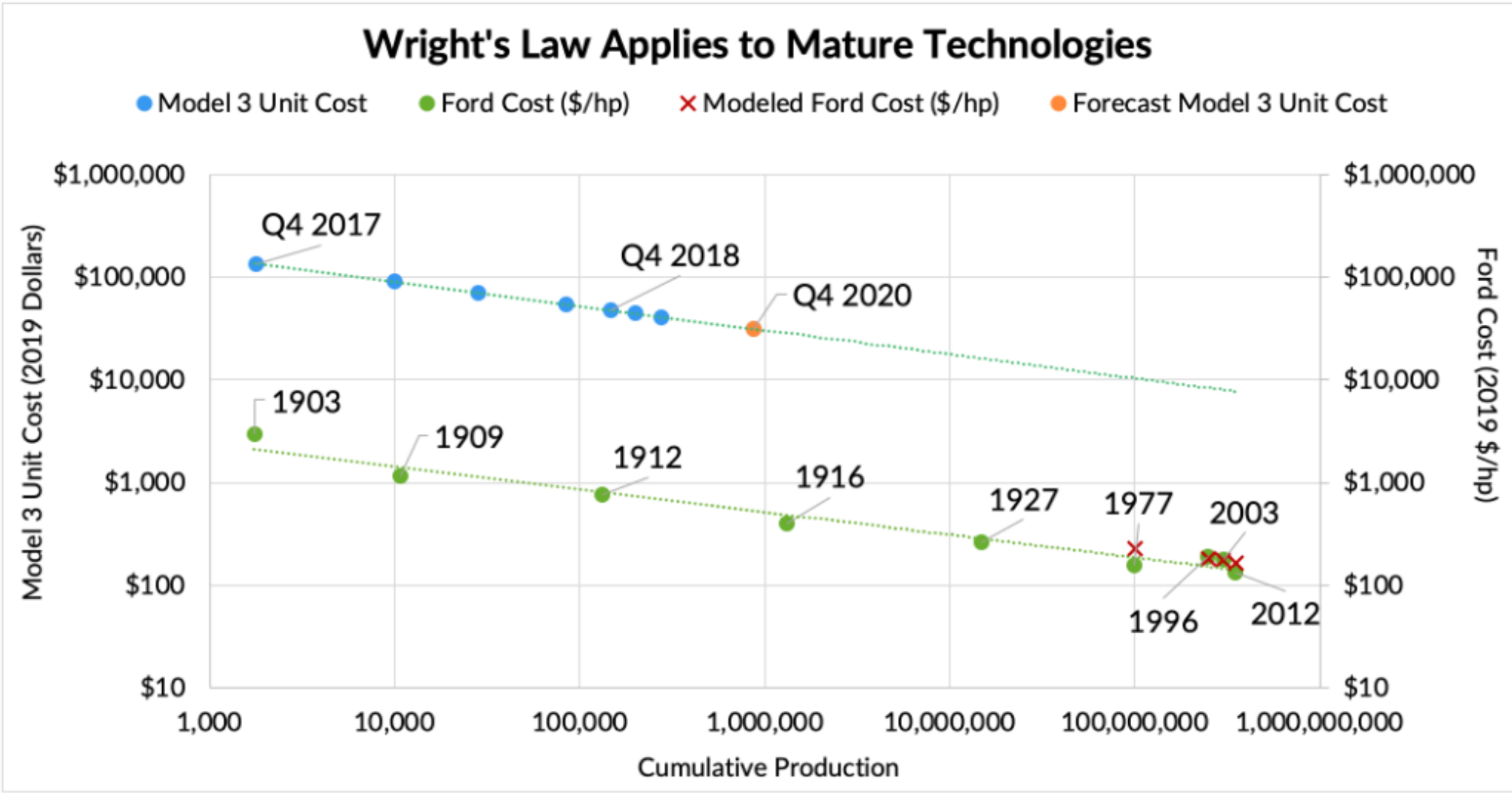
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EXHIBIT I Price of Model T. 1909-1923 (Average List Price in 1958 Dollars)



Source: <https://hbr.org/1974/09/limits-of-the-learning-curve>

BESS - THE NEXUS OF ALL ENERGY

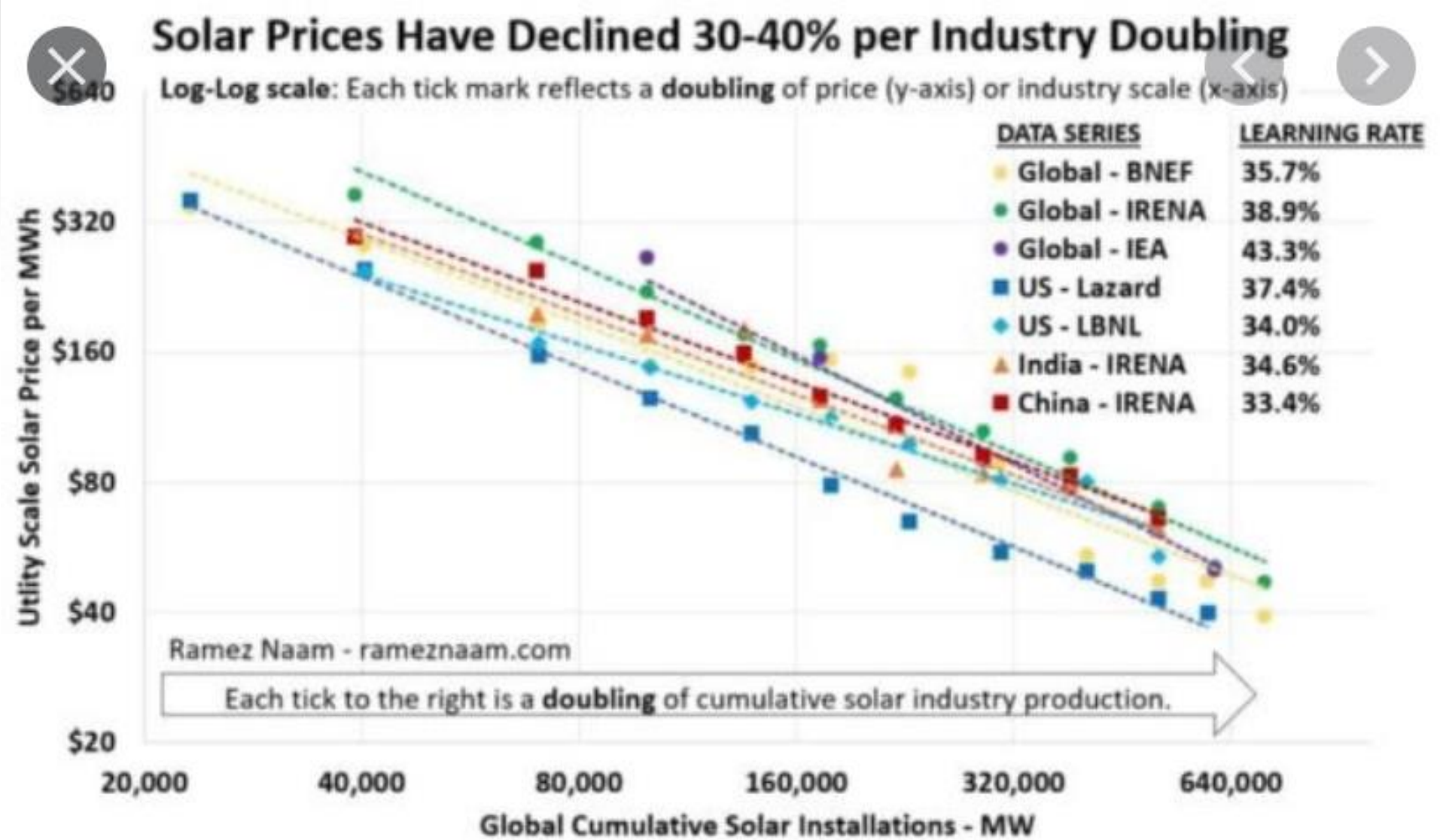


Source: ARK Investment Management LLC, 2019 | ark-invest.com

SOURCE: <https://ark-invest.com/analyst-research/wrights-law-predicts-teslas-gross-margin/>



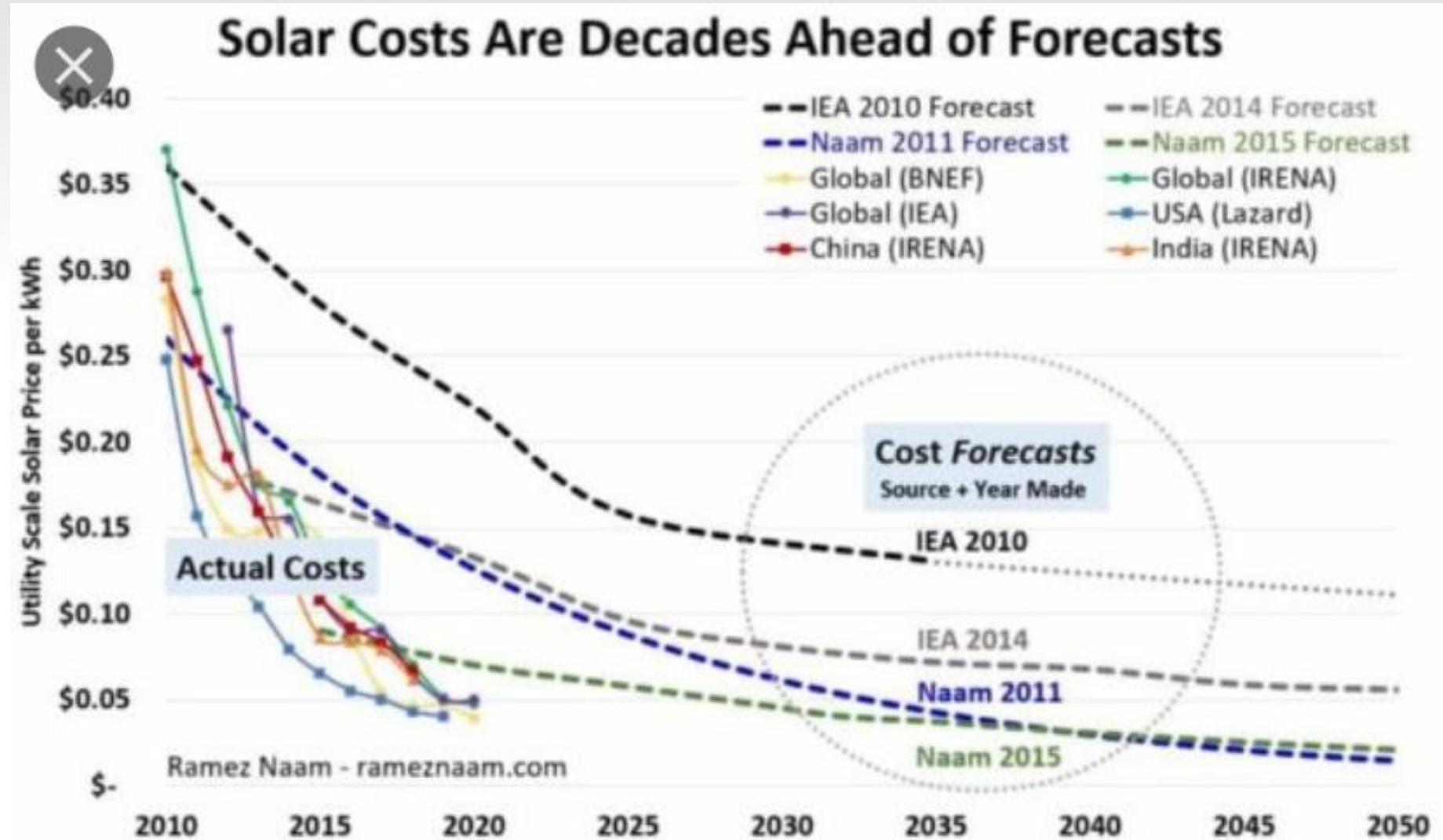
BESS - THE NEXUS OF ALL ENERGY



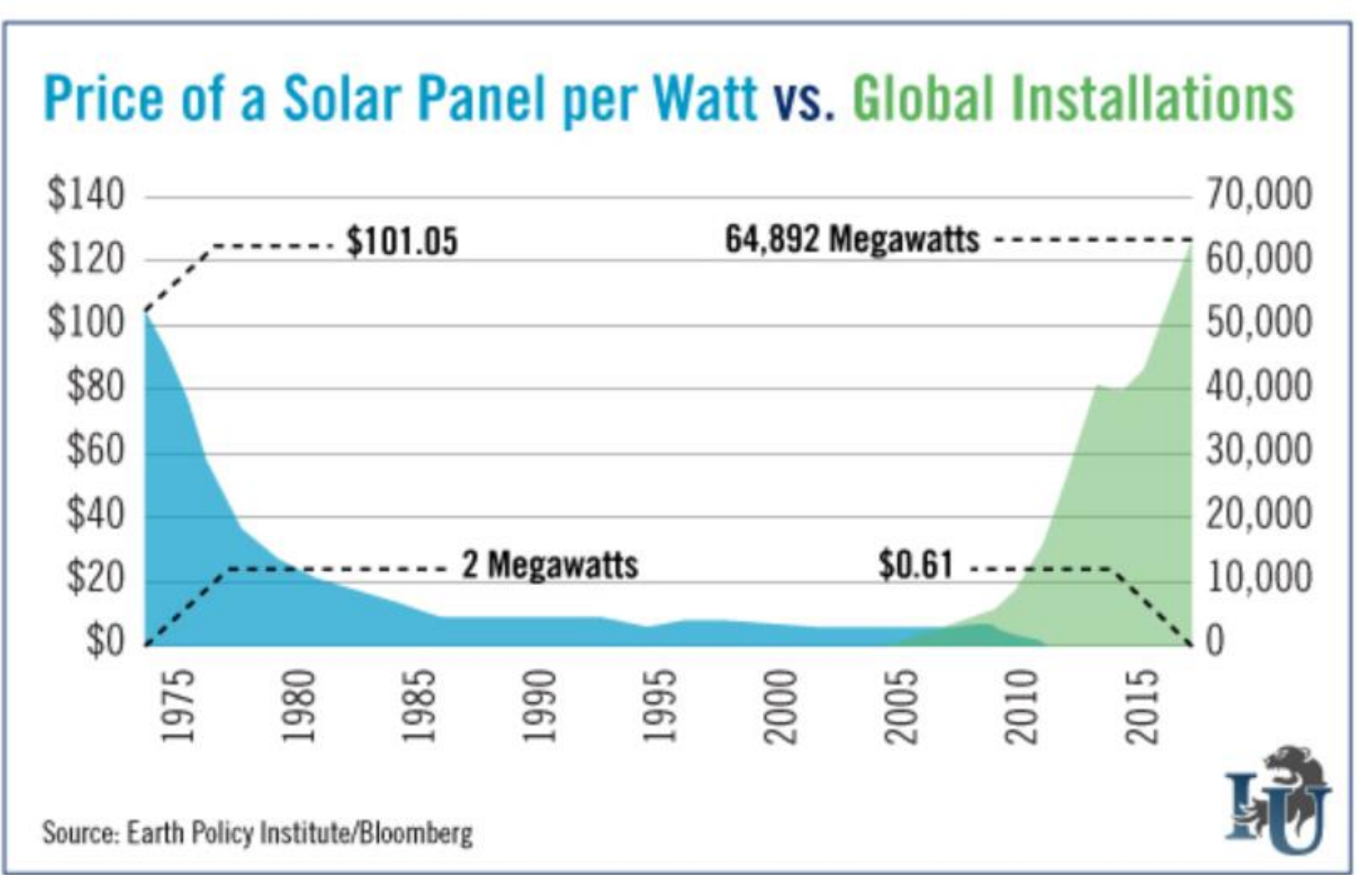
SOURCE: <https://pv-magazine-usa.com/2020/05/19/sunny-places-could-see-average-solar-prices-of-0-01-or-0-02-per-kilowatt-hour-within-15-years/>

BESS - THE NEXUS OF ALL ENERGY

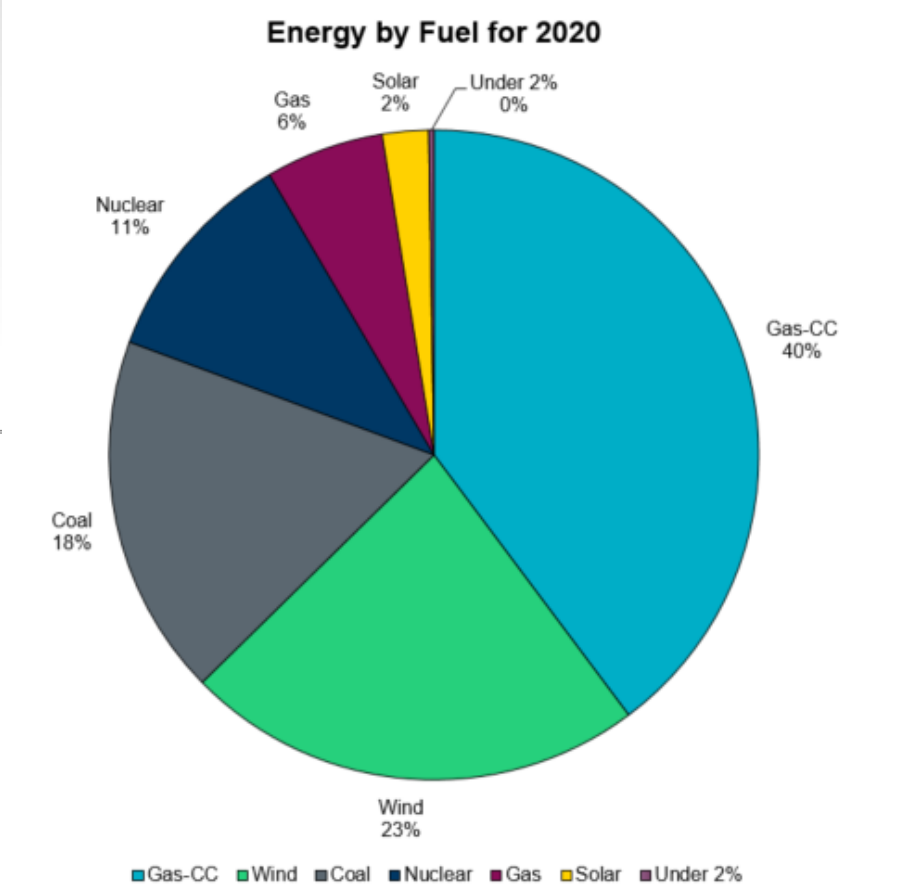
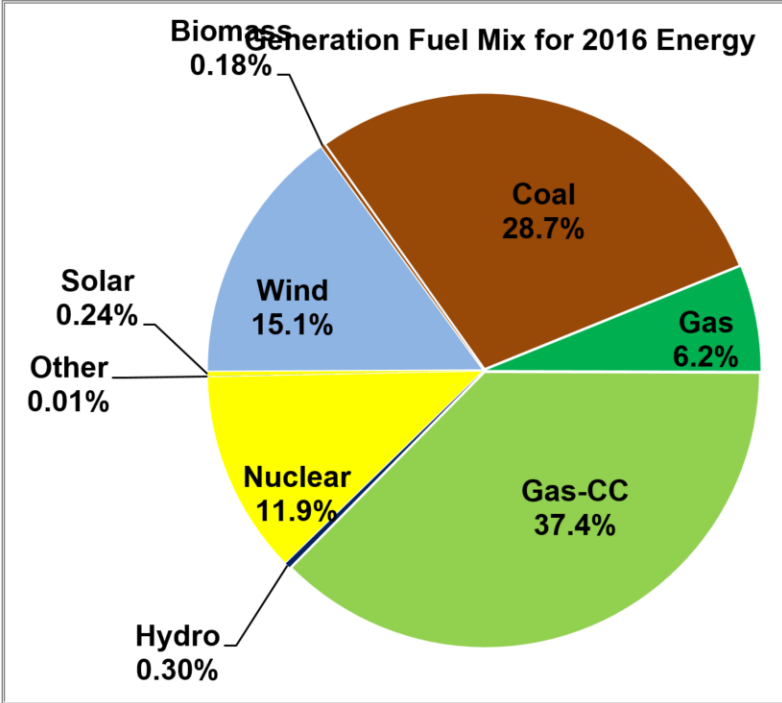
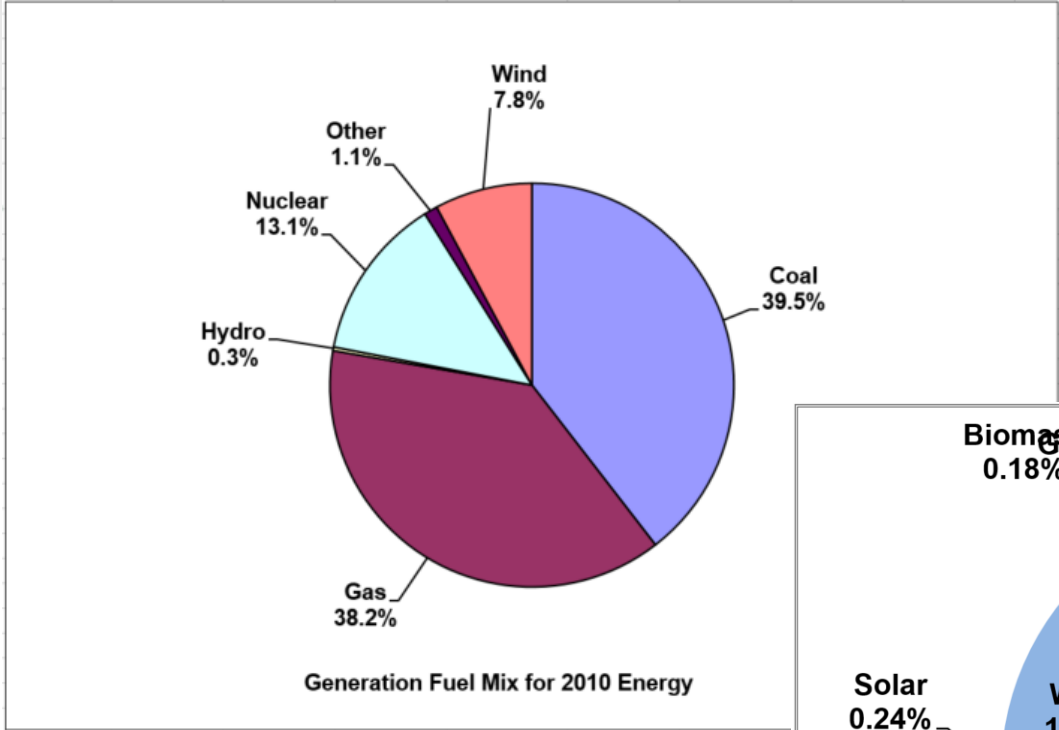
Sunny places could see average solar prices of \$0.01 or \$0.02 per kilowatt-hour within 15 years
PV Magazine
May 19, 2020



BESS - THE NEXUS OF ALL ENERGY



BESS - THE NEXUS OF ALL ENERGY – Texas Energy Generation



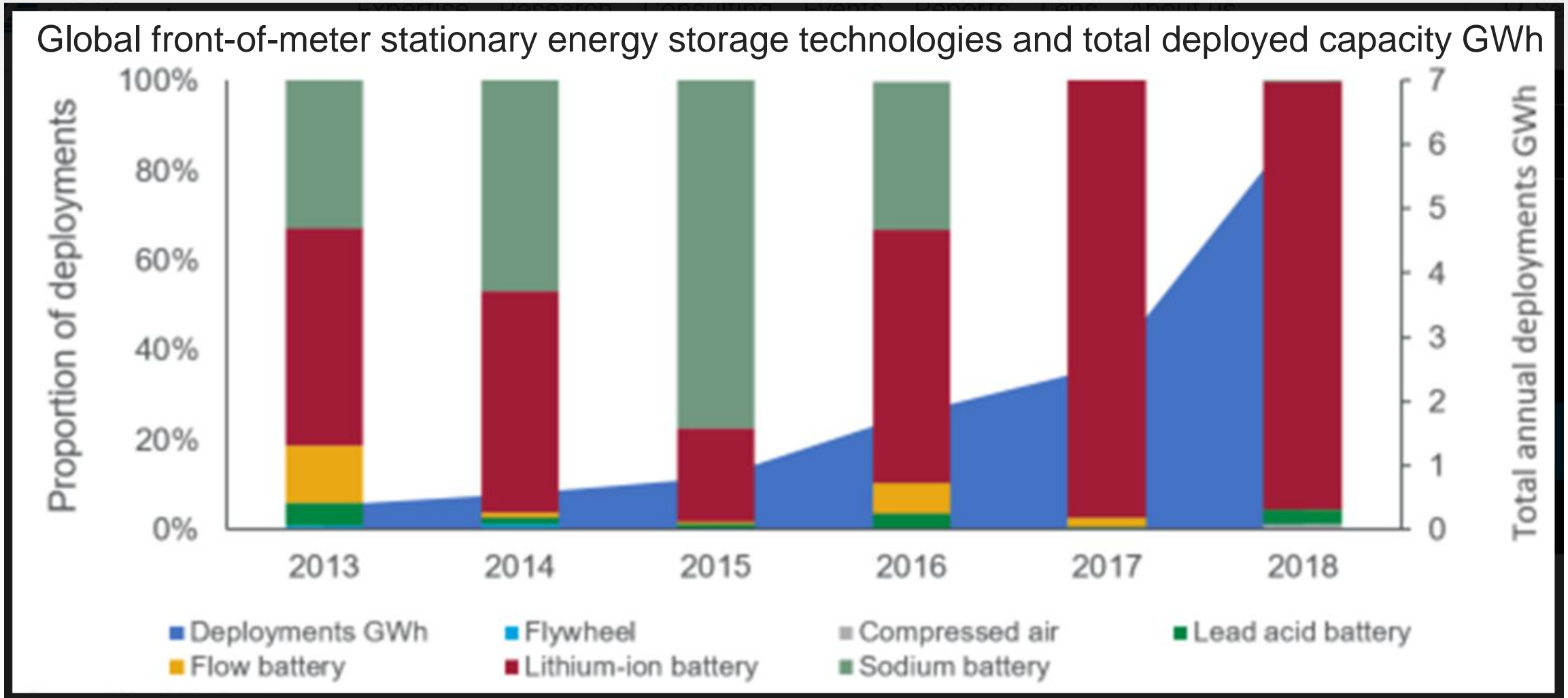
Source: ERCOT

BESS - THE NEXUS OF ALL ENERGY – THE FUTURE OF ENERGY IS IN STORAGE



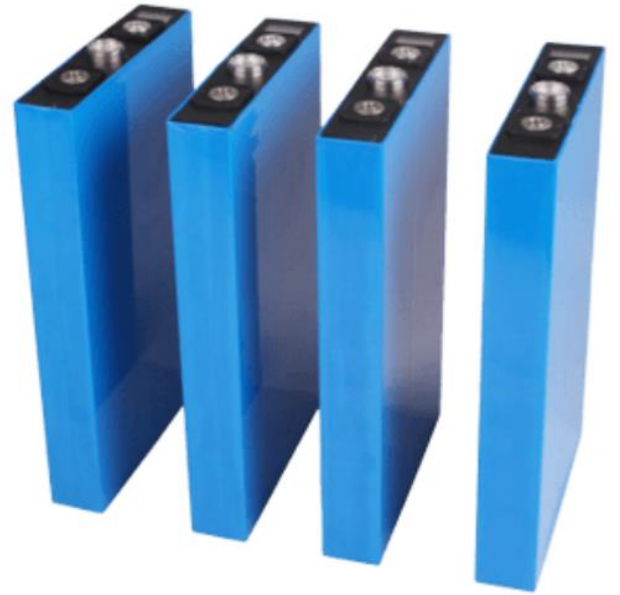
BESS - THE NEXUS OF ALL ENERGY

Don't fight the standard! (Li Ion Batteries ARE the standard.)



BESS - THE NEXUS OF ALL ENERGY – THE FUTURE OF ENERGY IS IN STORAGE

Lithium Ion Cells – Chemistry, Capacity, Format, etc.



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Modular Development



NMC 24V standard



NMC 24V air-cooled



NMC 24V liquid-cooled



NMC 48V standard



NMC 48V air-cooled



NMC 48V liquid-cooled



NMC 103V liquid-cooled



NMC 36V standard



NMC 40V standard



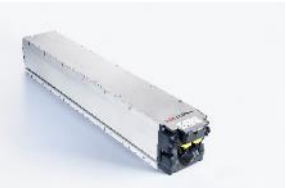
NMC 40V liquid-cooled



LTO 48V standard



LTO 83V standard



LTO 83V long



LFP 24V standard



NMC 48V Pouch



2x8 LFP round cell module



3x8 LFP round cell module



4x9 LFP round cell module

Electrifying High-Performing Applications

V+LTAPOWER®

Public
Transport
(Buses)



Intra-
logistics



Mining



Agriculture
&
Construc-
tion



BESS - THE NEXUS OF ALL ENERGY



...Partner for Electrifying High-Performing Applications*

VOLTAPOWER®

Public Transport (Buses)



Intra-logistics



Mining



Agriculture & Construction



* Excerpt from customer/application portfolio.

BESS - THE NEXUS OF ALL ENERGY

Transportation – The big revolution

Figure 13: Evolution of battery pack design

ICE/BEV architecture, 1st generation
Example: VW's e-Golf pack

BEV architecture, 2nd generation
Example: GM's Ultium platform

BEV architecture, 3rd generation
Example: BYD's Blade Battery

BEV architecture, 4th generation
Example: Tesla's cell-to-chassis platform

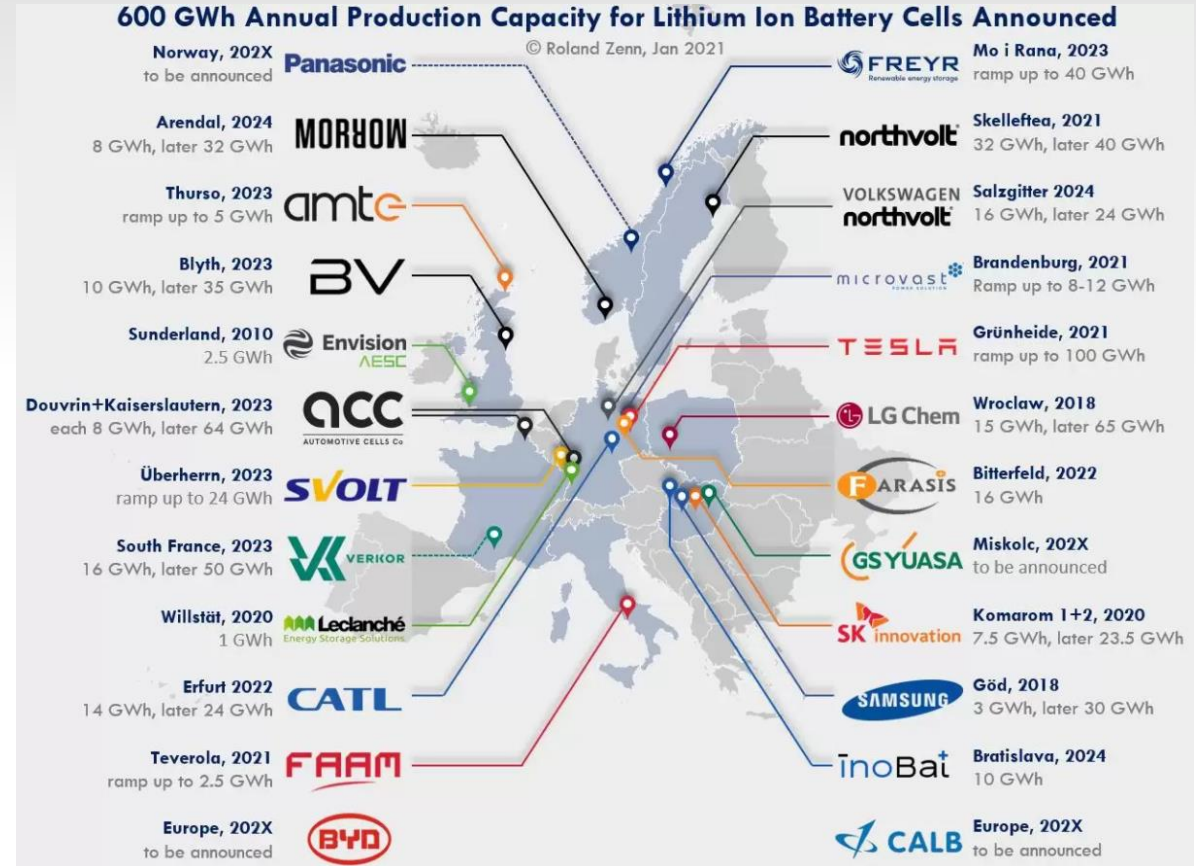
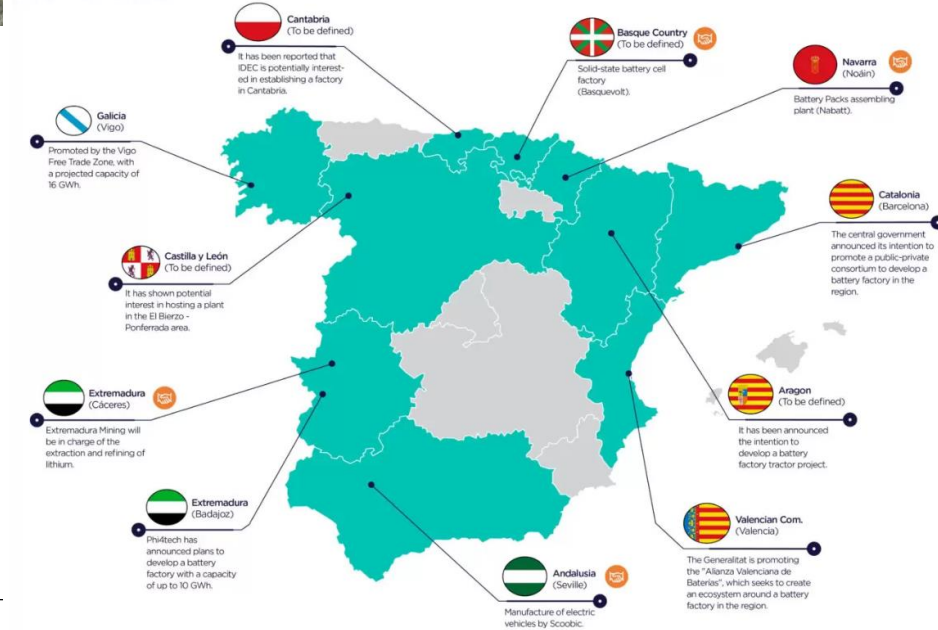


Source: Volkswagen, General Motors, BYD, Tesla

BESS - THE NEXUS OF ALL ENERGY – WRIGHT’S LAW > Gigafactory

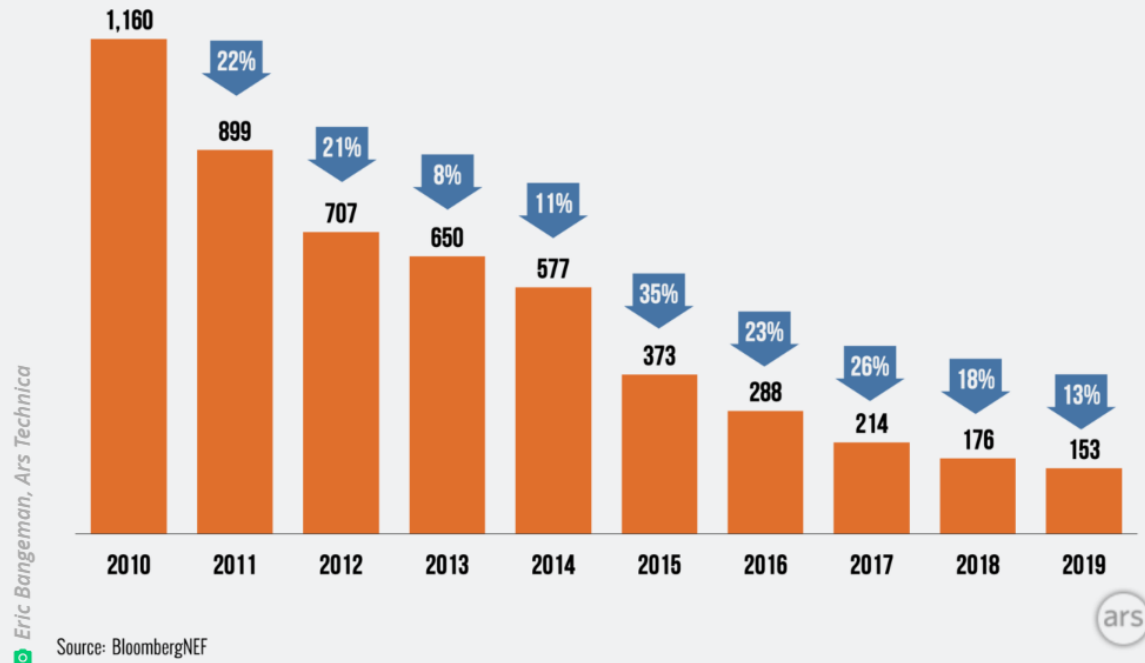


Analysis by CIC energIGUNE
(based on recent announcements)



BESS - THE NEXUS OF ALL ENERGY – WRIGHT’S LAW – Economies of Scale

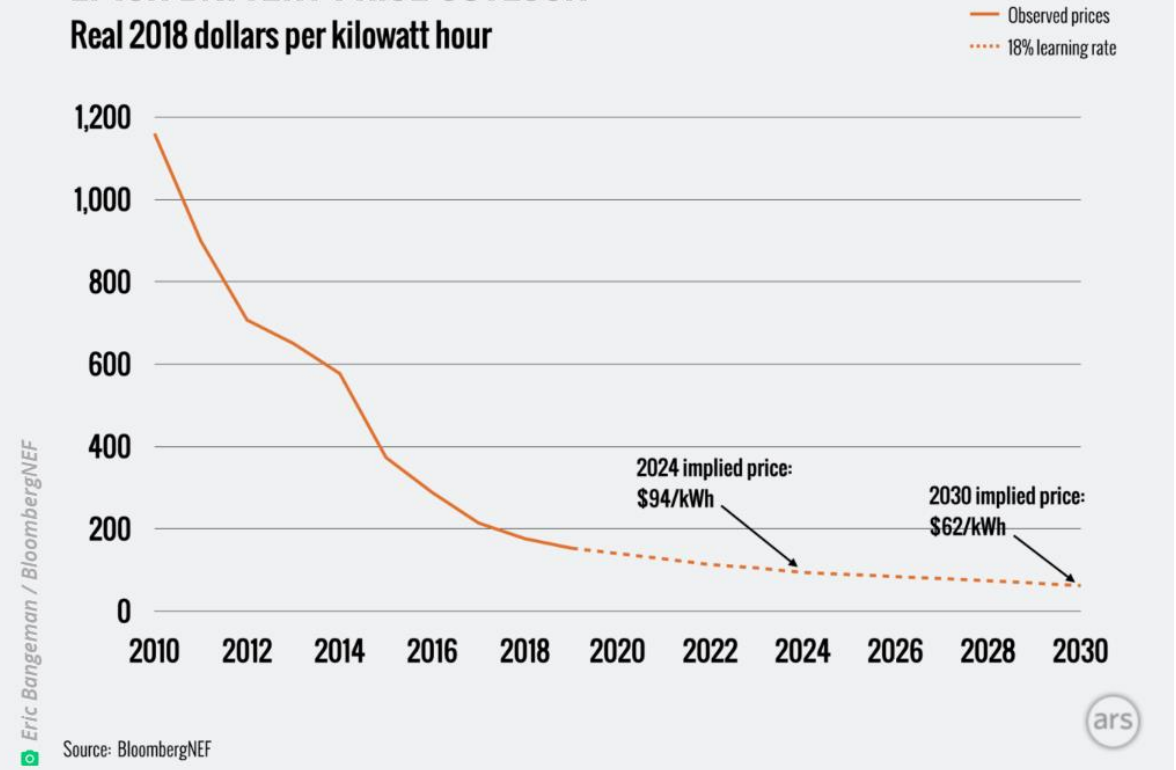
PRICE OF A LI-ION BATTERY PACK, VOLUME-WEIGHTED AVERAGE
Real 2018 dollars per kilowatt hour



\$100/kWh is considered “par” with ICE

LI-ION BATTERY PRICE OUTLOOK

Real 2018 dollars per kilowatt hour



Source: ars TECHNICA

BESS - THE NEXUS OF ALL ENERGY – WRIGHT’S LAW – Economies of Scale

THE FUTURE OF ENERGY IS IN LITHIUM ION BATTERIES

Lithium-ion has a significant advantage over alternative storage technologies: economies of scale. Source: Wood Mackenzie

Lithium-ion made up 95% of the global stationary energy storage technology market last year. And it is set to dominate this landscape for the next 10 years. Source: Wood Mackenzie

The cost of a lithium-ion battery rack for a storage system has dropped by 85% since 2010. Source: Wood Mackenzie

Manufacturing capacity has scaled from 14 GWh to 285 GWh in the same period and is on track to more than double to 777 GWh by 2026. Source: Wood Mackenzie

And we expect prices to continue to drop by an average of 9% each year until 2026. Source: Wood Mackenzie

Global lithium-ion cell manufacturing capacity pipeline could rise fourfold to reach 1.3 terawatt-hour (TWh) in 2030 compared to 2019. Source: Wood Mackenzie

BESS - THE NEXUS OF ALL ENERGY – Li Ion Technology Challenges

- Cost - EV / BEV / PHEV vs ICE Cost (CAPEX versus OPEX)
 - Cell Cost Reduction (\$/kWh)
 - Specific Energy (Wh/Kg)
- Range & Range Anxiety
 - Specific Energy
 - Charger Network Access
- Battery Life - Replacement at EOL (8 year warranty)
 - Life Cycle Increase
 - 1 Million Mile Battery
- Charge Time
 - Specific Power (C-Rates)
- Thermal Events (Fires)
 - Safety Improvements (including electrolytes)

BESS - THE NEXUS OF ALL ENERGY – Li Ion Technology Advancements

- Cobalt Reduced / Cobalt Free Cathodes – NMC 111 > 532 > 811>955
- Inorganic Electrolyte – (Ref: New Dominion Enterprises)
- Aerogel Electrode – (Ref: Dr. Buddie Mullins & Altect)
- Solid State – Glass – (Ref: Dr. John Goodenough and Dr. Maria Helena Braga)
- Solid State – LLNL Polymer Ceramic Electrolyte
- Amorphous Lithium Anodes – (Life, Safety and Energy) Idaho National Lab
- Single Crystal Electrodes – especially graphite anodes.
- Tab-less Design – (Ref: Tesla) //// Dry Battery Electrode – (Ref: Maxwell)
- Electrode Coatings / Electrolyte additives /// Cell formats & sizes 18650+++
- Polymer Cells /// Hybrid Lithium Metal /// Lithium Metal Cells /// Ceramic Separator
 - allowing cells to yield 30-50% greater Specific Energy while being safer.
 - Lithium Ion = 250Wh/kg....Lithium = 12,000Wh/kg

BESS - THE NEXUS OF ALL ENERGY - MOBILITY



BESS - THE NEXUS OF ALL ENERGY – STATIONARY - μ Sec monitor/msec response

Utility Scale Energy

Voltage Support

Frequency Control

T&D Avoidance

Feeder Line Support

Reactive Power

Load Following

Energy Imbalance

Distributed Generation

Time Shifting

Variable Generation
Smoothing

DERs - Residential

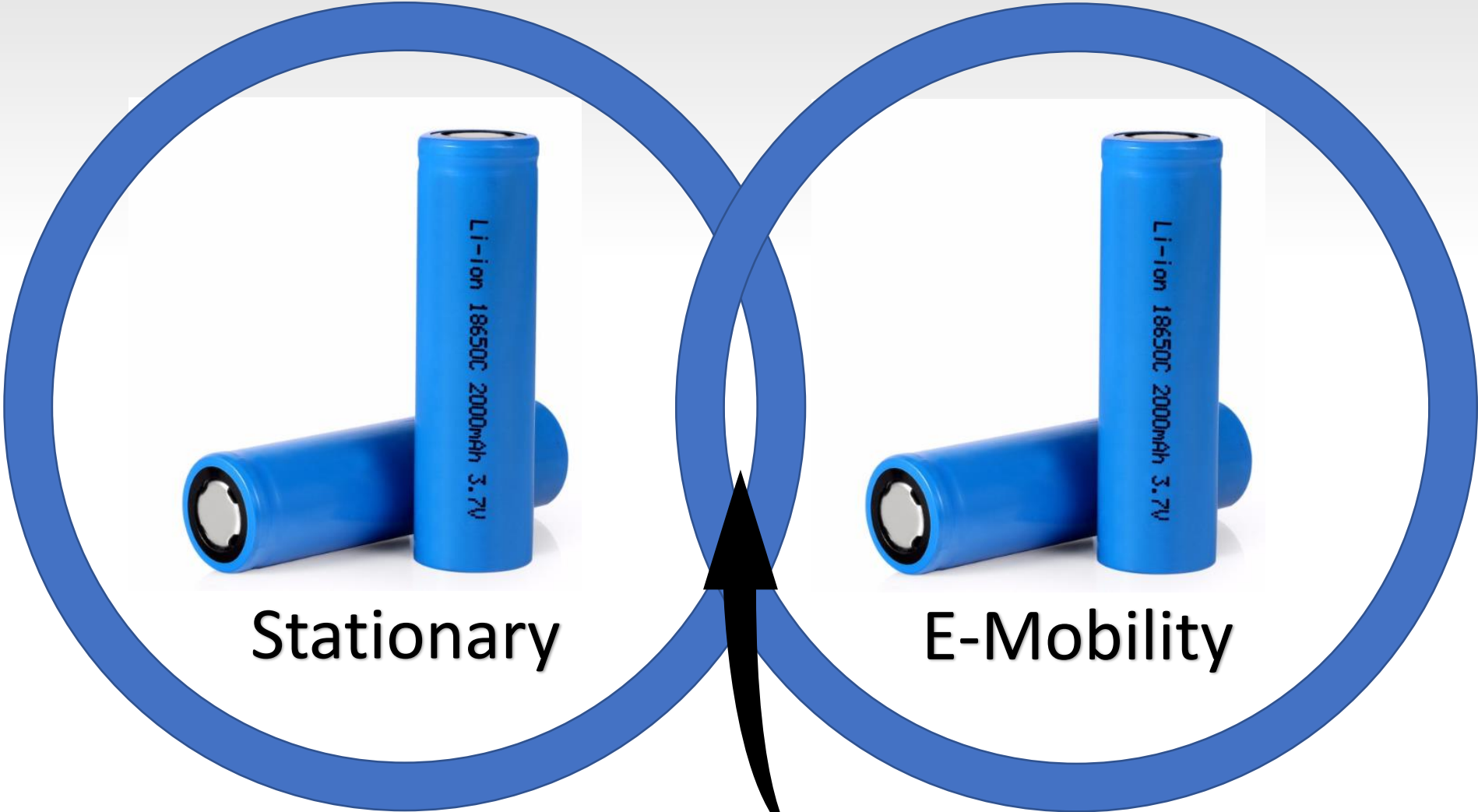
DERs - Utility

Panel Level
Storage

Behind the
Meter Storage



BESS - THE NEXUS OF ALL ENERGY – TWO WORLDS COLLIDE



Stationary

E-Mobility

The Future happens here!

BESS - THE NEXUS OF ALL ENERGY – THE (NEAR) FUTURE HAPPENS HERE

- V2G – Vehicle to Grid
 - Bilateral-capable vehicle
 - Bilateral-capable charger
 - Software to communicate with the grid
- V2B – Vehicle to Building
- V2H – Vehicle to Home
- V2V – Vehicle to Vehicle
- V2X – Vehicle to (anything)
- VPP – Virtual Power Plant
- VPPA – Virtual Power Purchase Agreement

BESS - THE NEXUS OF ALL ENERGY – THE (NEAR) FUTURE – Virtual Power Plant



SOURCE: <https://www.bakerhomeenergy.com/about/sunpower-elite-dealer>
SOURCE: https://www.generac.com/pwrcell-competitors?CID=ga-search-tesla&model=925&gclid=EAlalQobChMIzp2Qjp_U8AIVgYJbCh1BWQfMEAAAYiAAEgLZO_D_BwE

SOURCE: Nissan

BESS - THE NEXUS OF ALL ENERGY – Virtual Power Plant – Tesla Autobidder

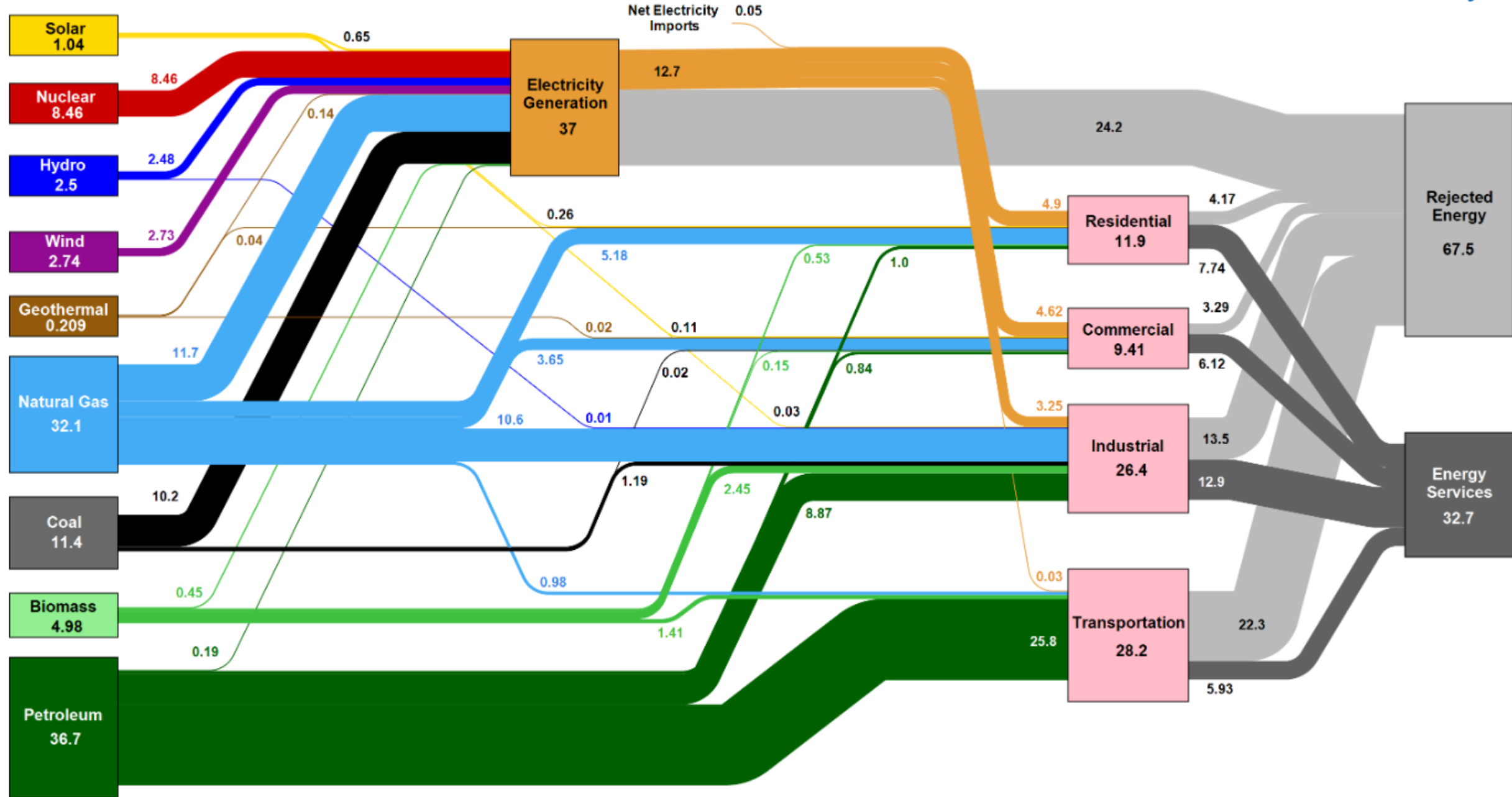


Autobidder

Autobidder provides independent power producers, utilities and capital partners the ability to autonomously monetize battery assets. Autobidder is a real-time trading and control platform that provides value-based asset management and portfolio optimization, enabling owners and operators to configure operational strategies that maximize revenue according to their business objectives and risk preferences. Autobidder is part of [Autonomous Control](#), Tesla's suite of optimization software solutions.

Autobidder is successfully operating at Hornsdale Power Reserve (HPR) in South Australia, and through market bidding, has [added competition to drive down energy prices](#).

Estimated U.S. Energy Consumption in 2019: 100.2 Quads



Voltabox - The Future of Energy – Q&A



Thank You!

V+LTABOX®