

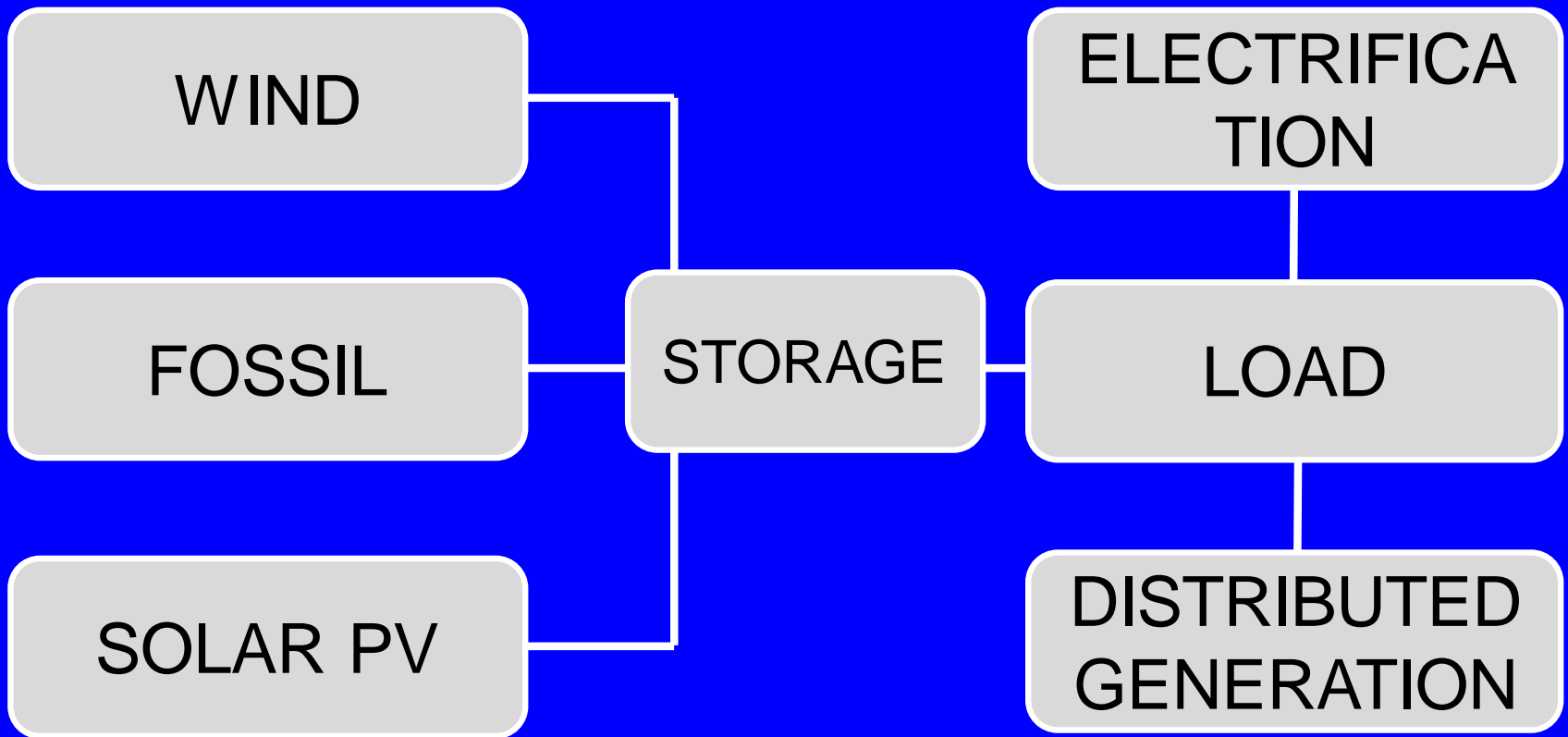
The Clean Electric Grid and the Growth of Energy Storage

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The grid used to be Simple
and Deterministic!



The grid has become stochastic!



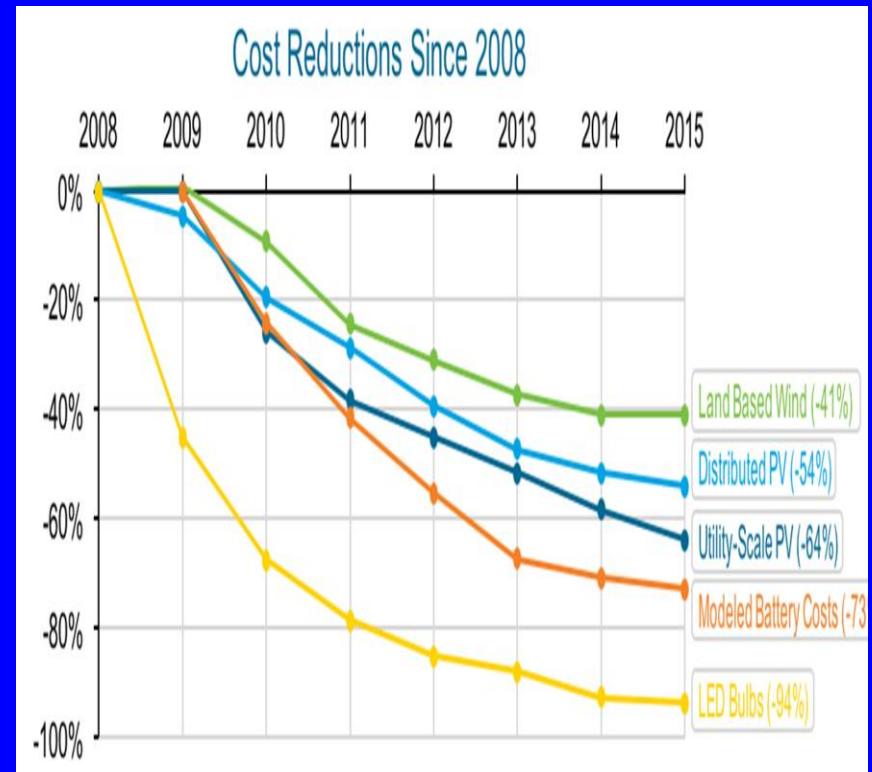
Changes are rapid and substantial

RENEWABLES

DISTRIBUTED
GENERATION

ELECTRIFICATION

DOE 2016



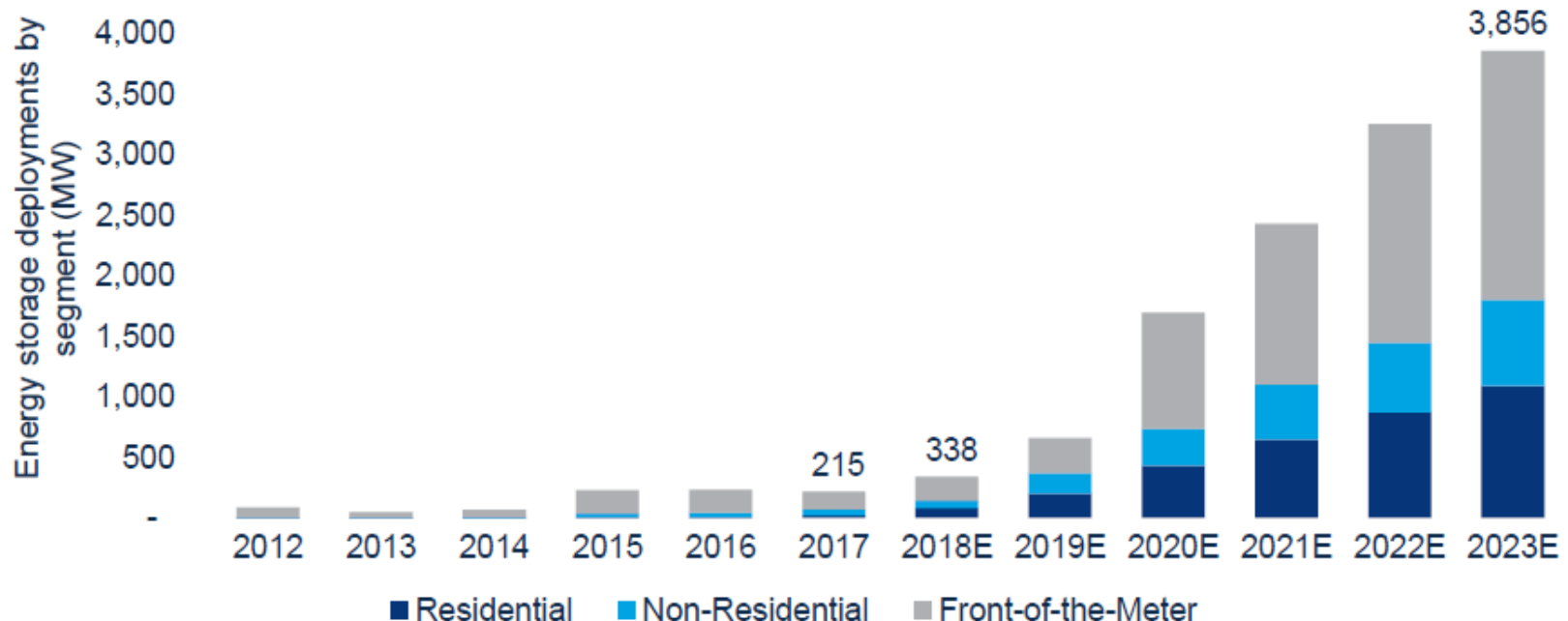
STORAGE

Energy Storage has become a Resounding Success!

U.S. energy storage annual deployments will reach 3.9 GW by 2023

Utility procurements, changing tariffs and grid service opportunities all drive the market forward

U.S. energy storage annual deployment forecast, 2012-2023E (MW)



Incumbent Lithium-Ion Technology:

Sourcing, Ecological, and Sociological Issues

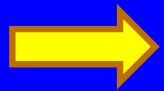
Safety, Reliability,

Re-Use, Recycling, Disposal

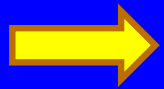


STORAGE REQUIREMENTS

- COST
- ADEQUATE SOURCING
- SAFETY
- RELIABILITY
- DURATION
- ENVIRONMENTAL ACCEPTANCE
- RECYCLABILITY / REUSE



EARTH-ABUNDENT MATERIALS



CIRCULAR ECONOMY



Safety must be of Paramount Concern

An Urgent Situation!

30 states, Washington, D.C., and 3 territories have adopted Renewable Portfolio Standards, while 7 states and 1 territory have set Renewable Energy Goals.

→ This requires Longer Duration Storage!

8 Hours – 12 Hours – Days – Seasons

High Penetration of Renewables
Needs bigger and longer lasting Storage!

Cost Goals for Focus Technologies

Manufactured at scale

Li-ion Batteries (cells) \$100/kWh

V/V Flow Batteries (stack+PE) \$300/kWh

Zinc Manganese Oxide (Zn-MnO₂)
2 Electron System \$ 50/kWh

Low Temperature Na / Na-ion
based Batteries \$ 60/kWh

Aqueous Soluble Organic (ASO)
Redox Flow Batteries (stack+PE) \$125/kWh

Advanced Lead Acid \$ 35/kWh

On the Horizon:

Vehicle to Grid – Fleets: School bus, Postal, Military

“Better” Lithium: Innolith (Aleo) / Non-Lithium Technologies
Vanadium Redox, Zinc-Bromine, Zinc-Manganese,
Iron-Chlorine (ESS), Ambri, Sodium (NGK),

Non-Battery Technologies:

Cement Blocks, Railroads, CAES, Pumped Hydro
Thermal Systems (Ice, PCMs, Aesthus, Malta, Liquid Air)

Long – Duration, Long Term Storage (8hrs, 12hrs, days)
Business Case? “Frozen” Electrolytes, Hybrid Systems,

Hydrogen, Ammonia, etc.

Now and in Future,
Energy Storage
should be in
the Toolbox of every Utility!