



## **Energy Storage: An Overview of PV+BESS, its Architecture, and Broader Market Trends**

**By  
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# INTRODUCTION – PRESENTATION OVERVIEW

Aaroh Kharaya, Director, Energy Storage Engineering,  
Primergy Solar

- 9+ years of experience in engineering solar, storage and construction industry globally.
- Subject matter expert in AC coupled, DC coupled storage system, Microgrids and DER
- Supported over 1.5 GW of BESS projects worldwide



# SOLAR + ENERGY STORAGE SYSTEM

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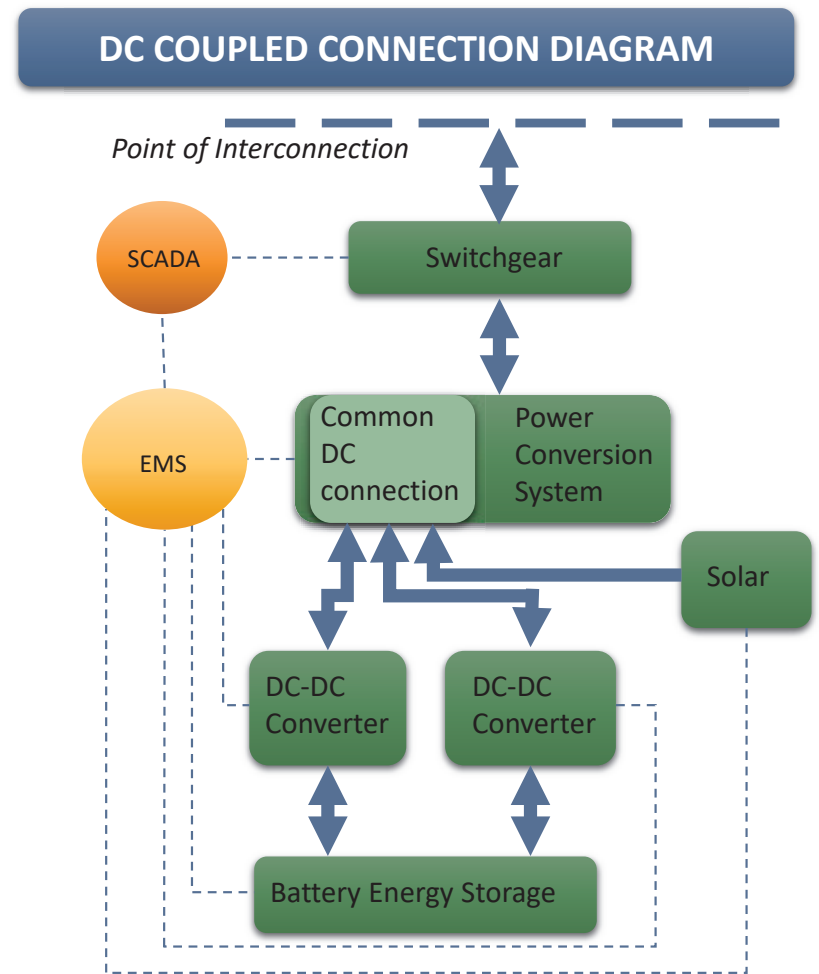
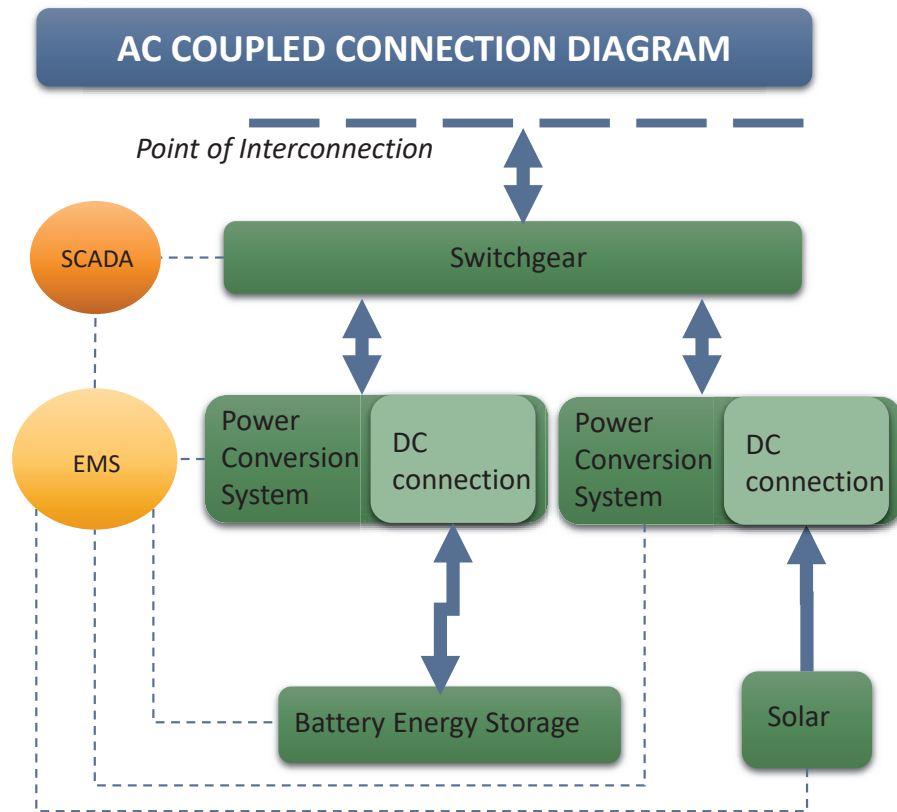
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SUMMARY

GEMINI SOLAR

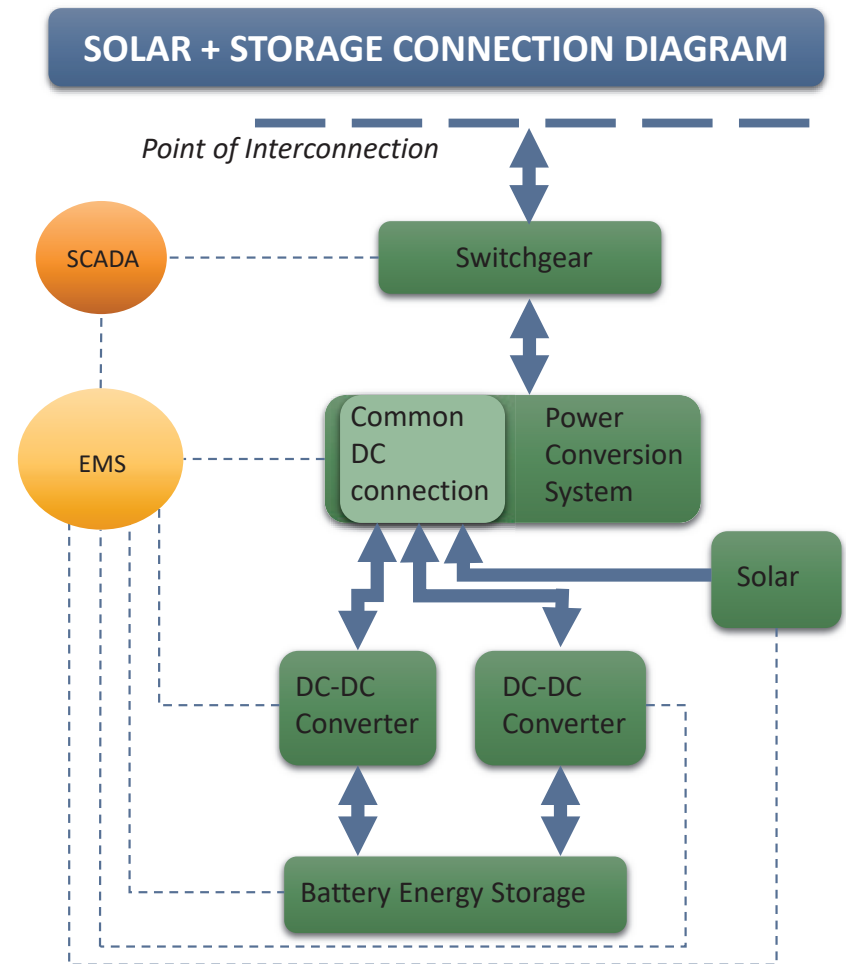
# WHAT IS SOLAR PLUS STORAGE



# WHAT IS DC COUPLED SOLAR PLUS STORAGE

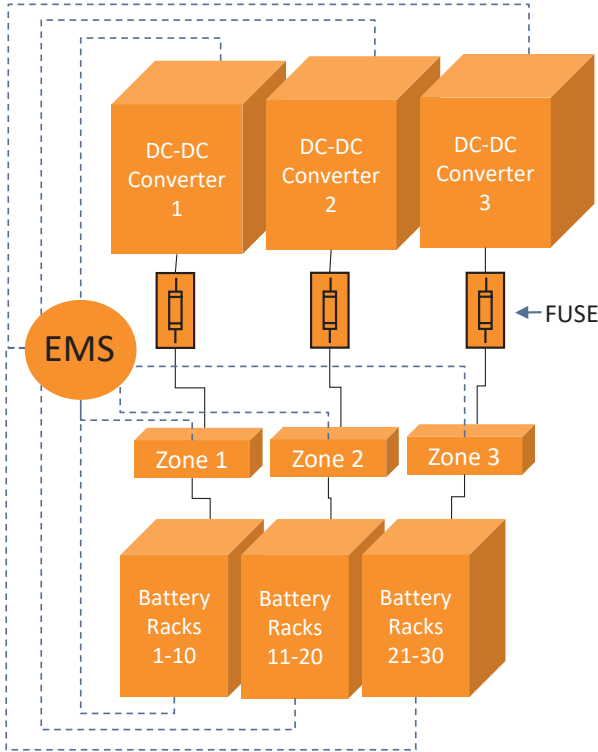
- Battery energy storage can be connected to new and existing solar via DC coupling
- Battery energy storage connects to DC-DC converter.
- DC-DC converter and solar are connected on common DC bus on the PCS.
- Energy Management System or EMS is responsible to provide seamless integration of DC coupled energy storage and solar.

- DC coupling of solar with energy storage offers multitude of benefits compared to AC coupled storage
  - Higher Round Trip Efficiency
  - Making solar a dispatchable asset
  - Higher returns of investment
  - Reduce interconnection hassle and cost



# DC CONVERTER CONNECTION ARCHITECTURE

## ONE DC CONVERTER PER ZONE



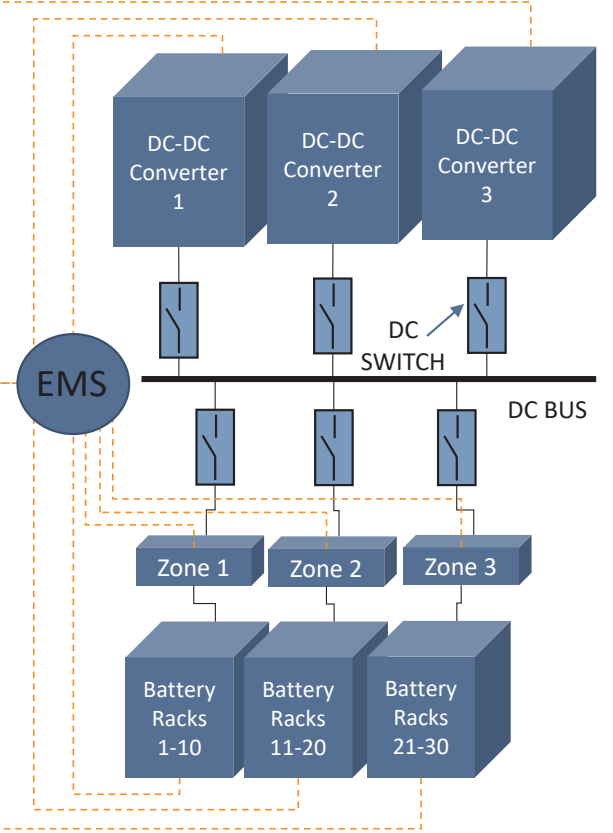
## ADVANTAGES

- Simpler Architecture
- Higher Flexibility
- Lower Balance of System Costs
- Higher System Availability
- Simpler EMS Integration

## DISADVANTAGES

- Lower Flexibility
- Complex Architecture
- Lower System Availability
- Higher Balance of System Costs
- Complex EMS Integration

## DC CONVERTERS ON COMMON DC BUS



# DC-DC CONVERTER MANUFACTURERS

While there is lots of interest around the world for DC coupled system, PCS vendor are behind launching new DC-DC Converter products

Dynapower, SMA and Power Electronics are performed and running successful PV plus solar projects in USA

Typical DC-DC converter sizes range from 250kW to 525kW.

SMA is using white label Dynapower's DC-DC converters with slight modifications to better integration with SMA Energy Storage product line



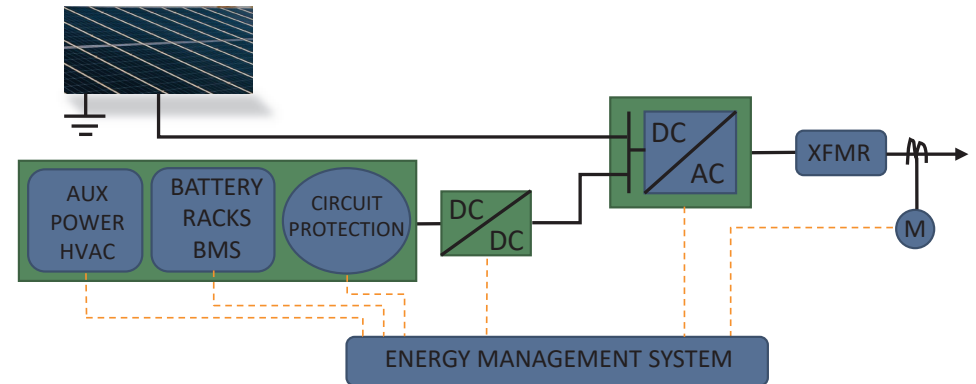


# TECHNICAL CHALLENGE OF DC COUPLED SYSTEM

Solar PV system are constructed negatively grounded in the USA. Until 2017, NEC code also leaned towards ground PV system

Grounded PV on negative terminal eliminates the risk of Potential-induced degradation of modules

However, if batteries are DC couple with solar, solar PV system needs to be ungrounded or galvanically isolated.



# ROUND TRIP EFFICIENCY COMPARISON

## AC COUPLED SYSTEM

### Round Trip Efficiency

$$(0.97 \times 0.98 \times 0.985) \times (0.985 \times 0.98 \times 0.97)$$

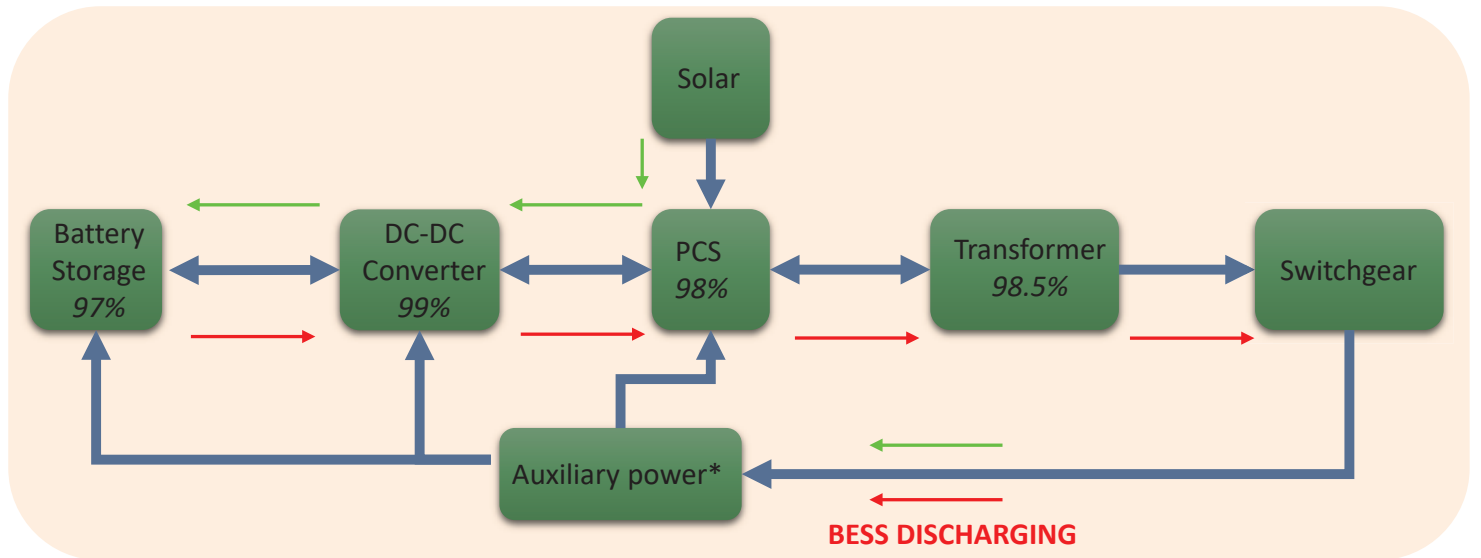
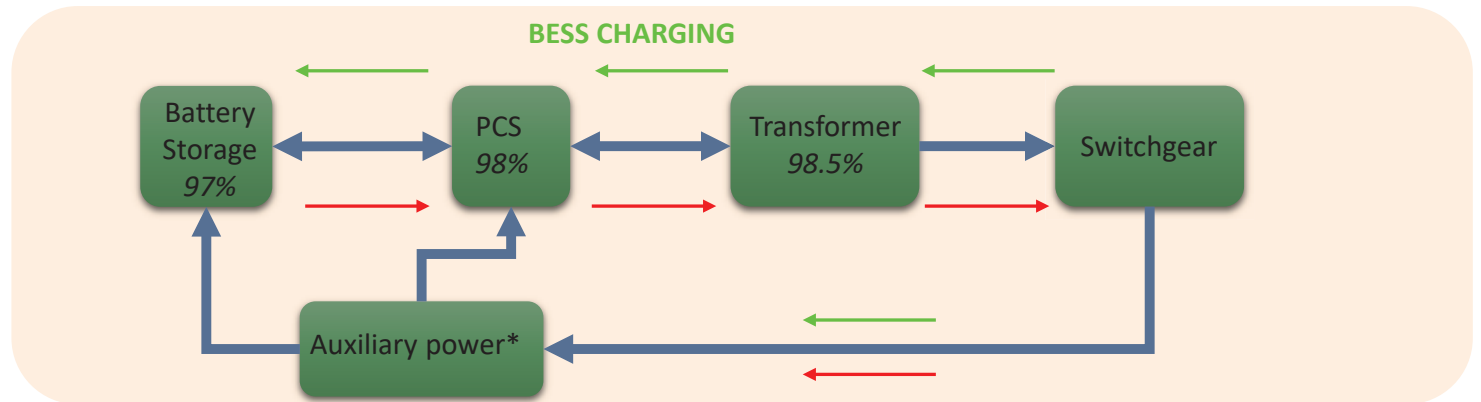
= 87.6%

## DC COUPLED SYSTEM

### Round Trip Efficiency

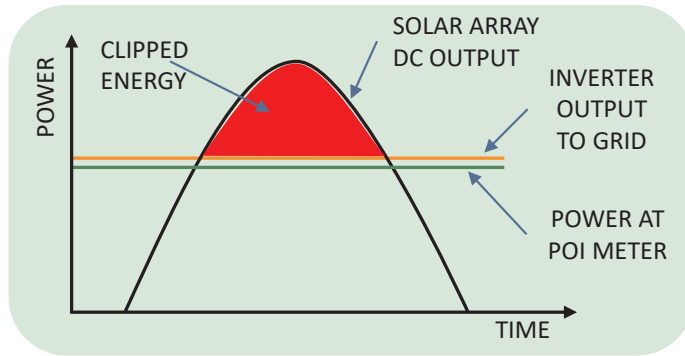
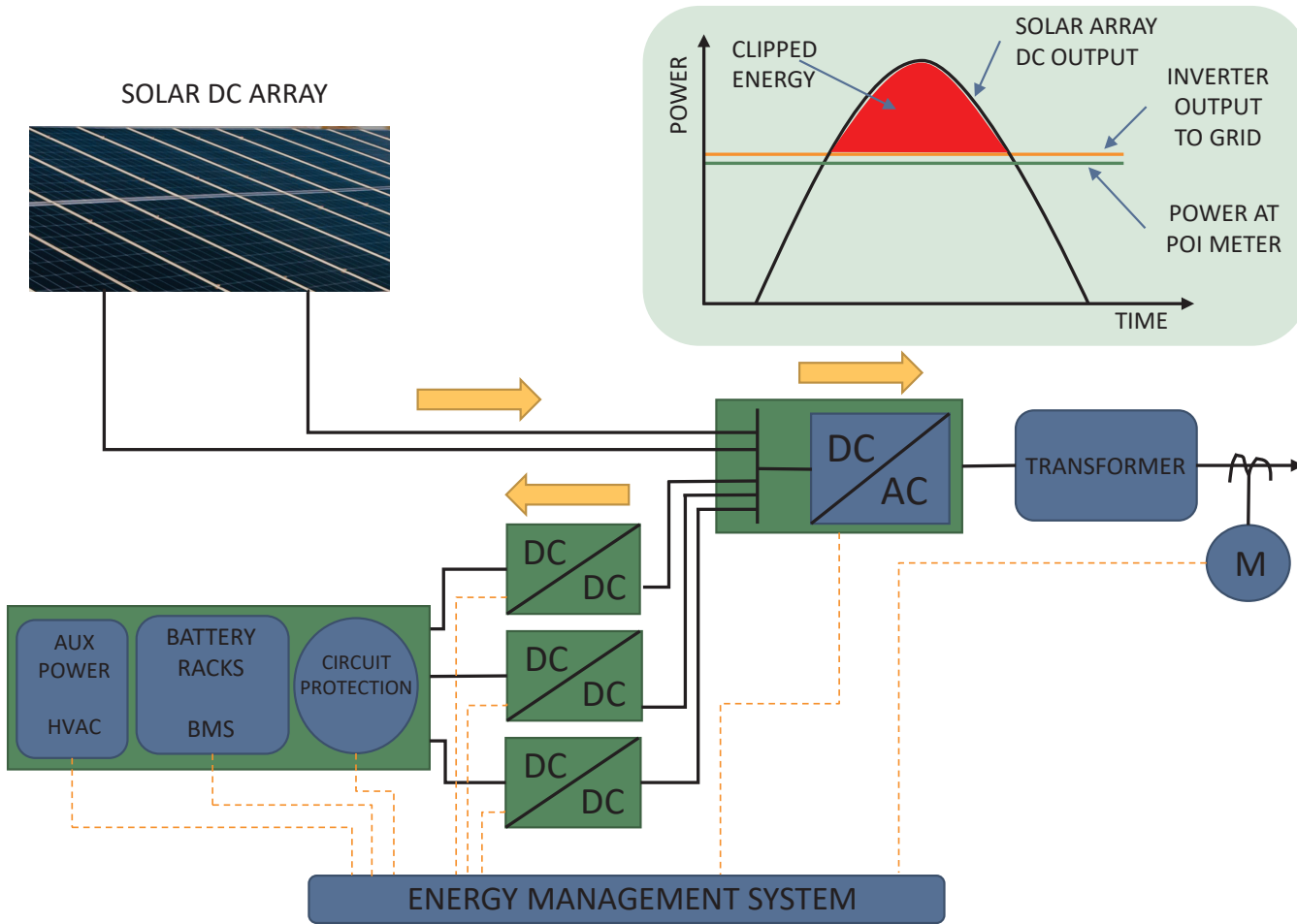
$$(0.99 \times 0.97) \times (0.97 \times 0.99 \times 0.98 \times 0.985)$$

= 89%



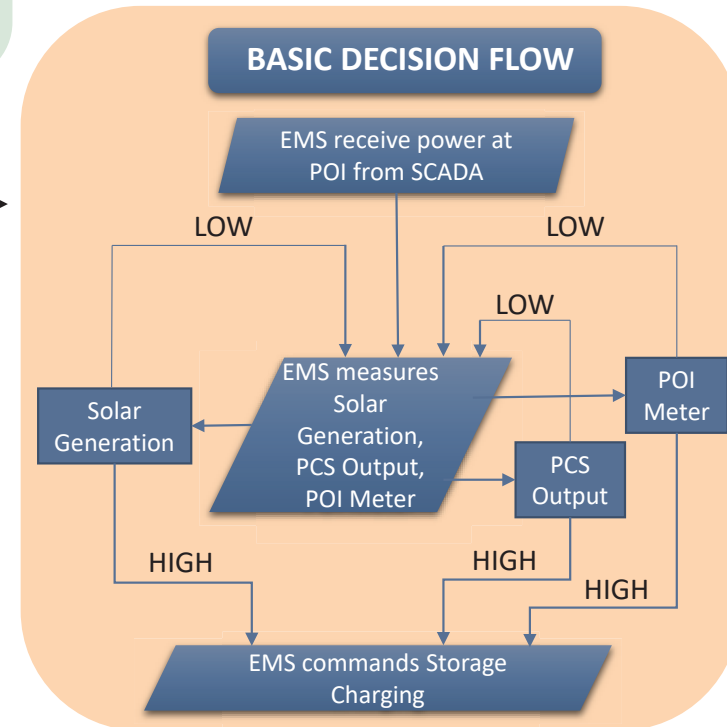
\* Auxiliary power consumption not assumed.

# ADDITIONAL VALUE STREAM – CLIPPING RECAPTURE

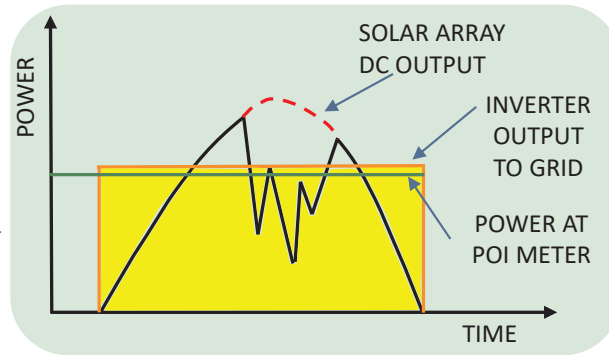
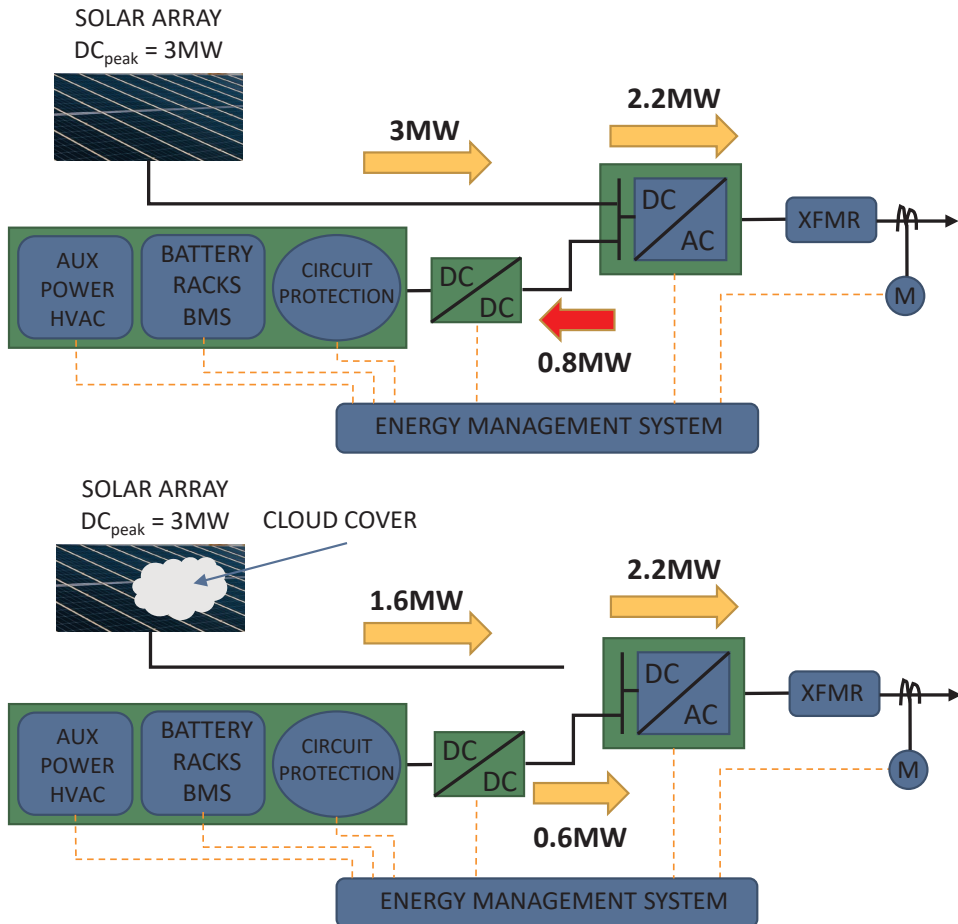


Clipping Recapture allows solar + storage system to capture all generated energy

Clipping Recapture allows to maximize Investment Tax Credits.

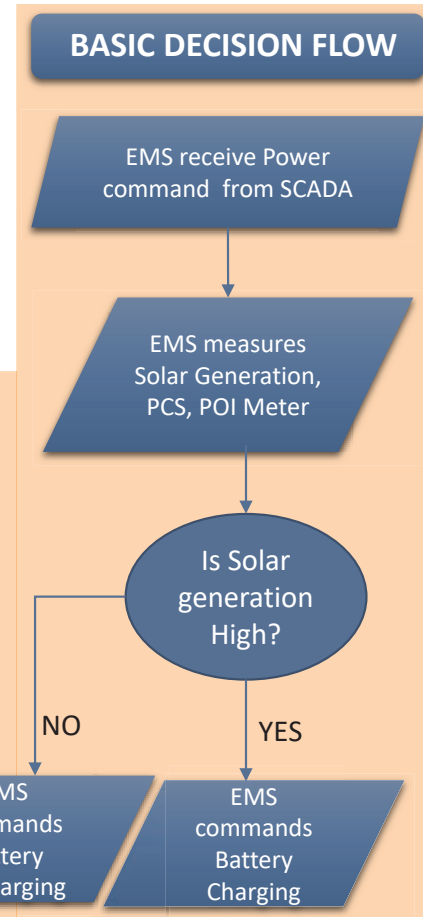


# ADDITIONAL VALUE STREAM – RENEWABLE SMOOTHING

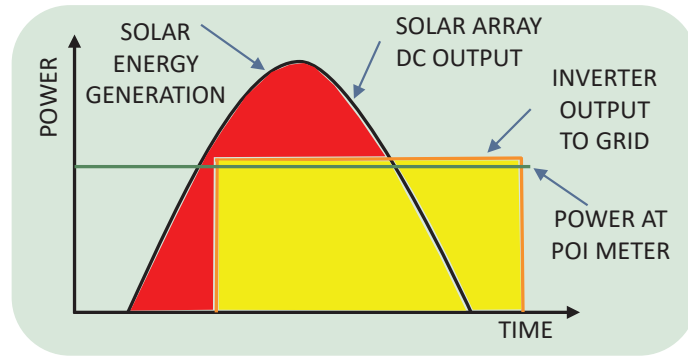
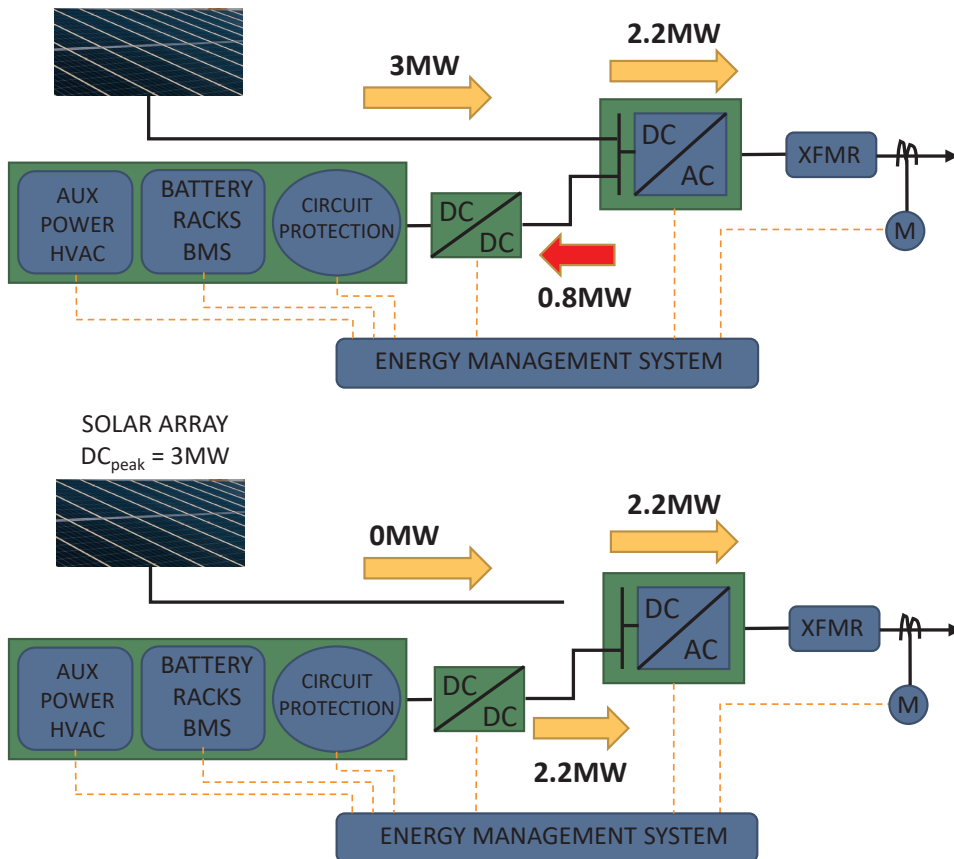


Solar generation is an intermittent energy. Solar Energy generation can fall from peak to zero in seconds.

DC Coupled energy storage can alleviate renewable intermittency and provide stable output at point of interconnection



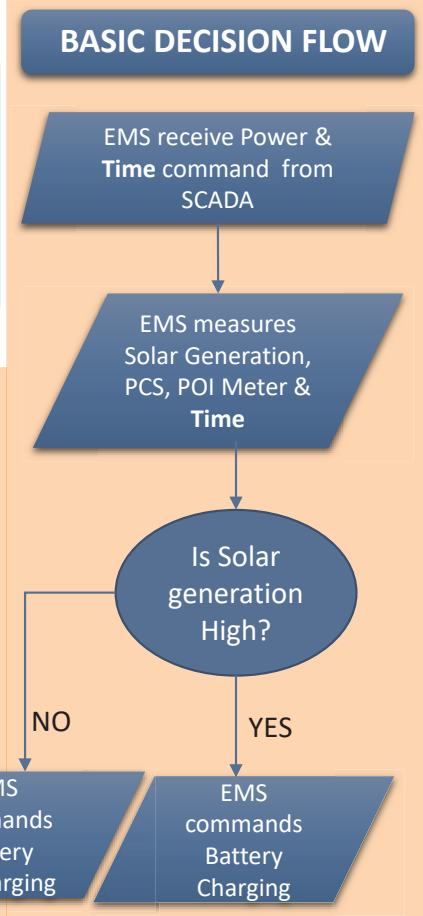
# ADDITIONAL VALUE STREAM – ASSET DISPATCH



DC coupled storage allows solar PV plant to become a dispatchable asset

Battery Energy Storage discharges through PV inverter to maintain constant power during no solar production

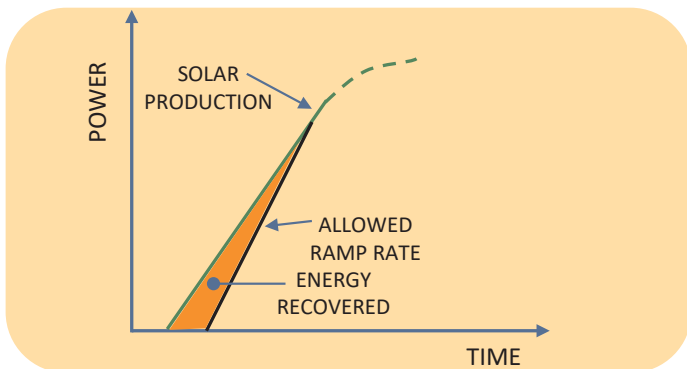
Battery Storage system size will be larger compared to Clipping Recapture and Renewable Smoothing use case



# ADDITIONAL VALUE STREAM

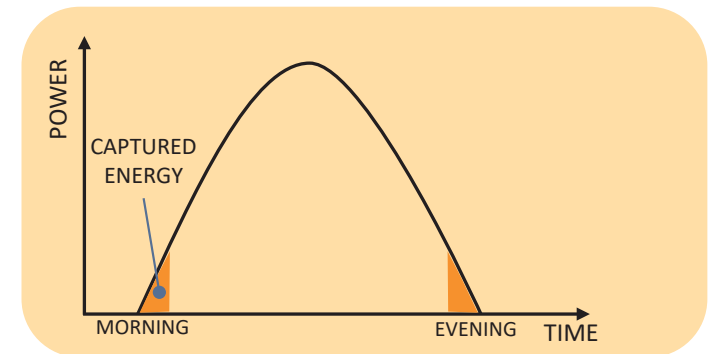
## RAMP RATE CONTROL

- Typically, utilities require fixed ramp rate to limit the amount of change of energy connected to the grid.
- DC coupled system can monitor ramp rate, solar energy generation and transfer additional energy to battery energy storage.
- Ramp Rate Control can provide additional revenue stack when coupled with other use-cases like clipping recapture etc.

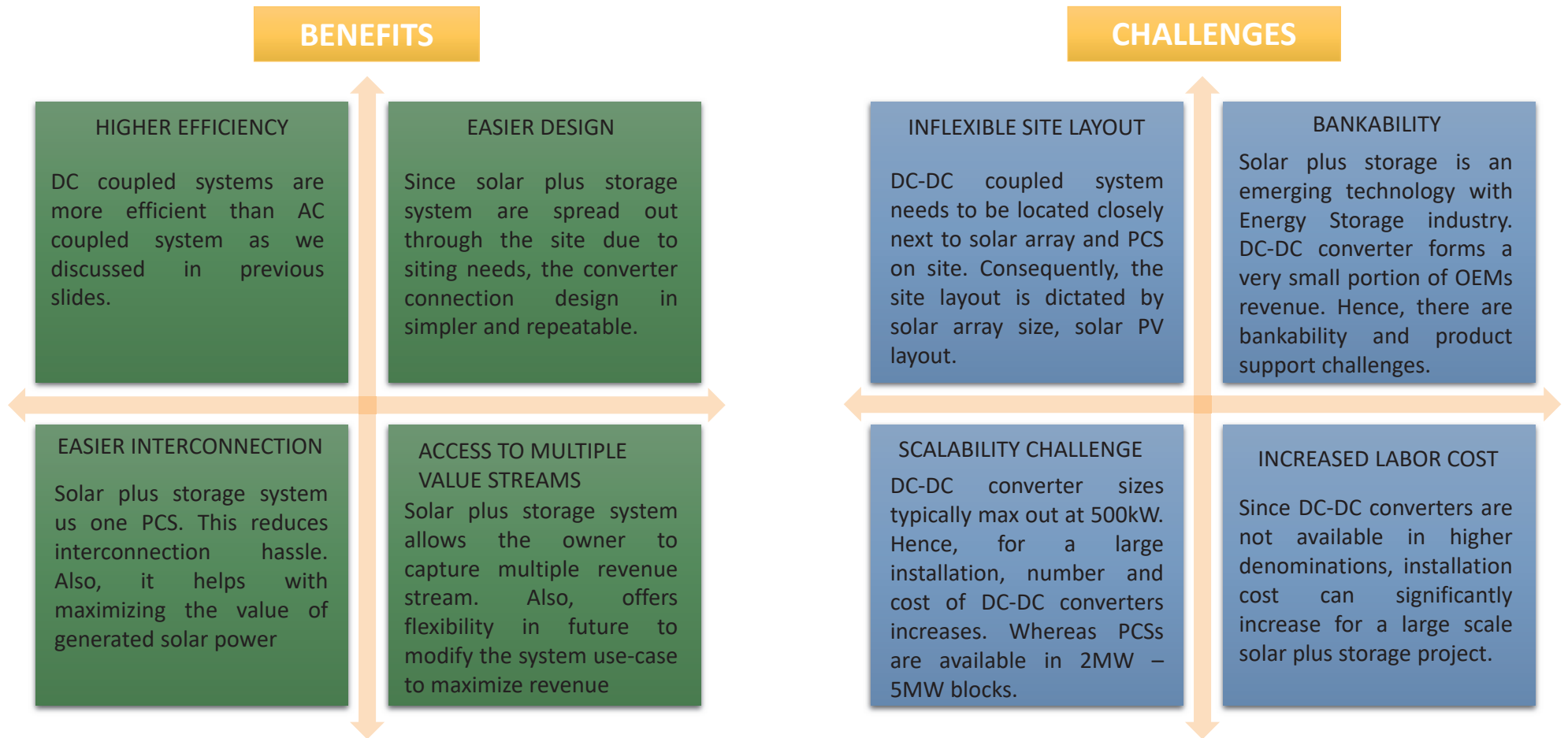


## LOW VOLTAGE HARVESTING

- Solar PV array generates low voltage during morning and evening period.
- If this voltage is below PV inverters threshold voltage, then solar energy generated at these low voltages is lost.
- DC coupled system can capture this energy and improve the value of project



# SUMMARY

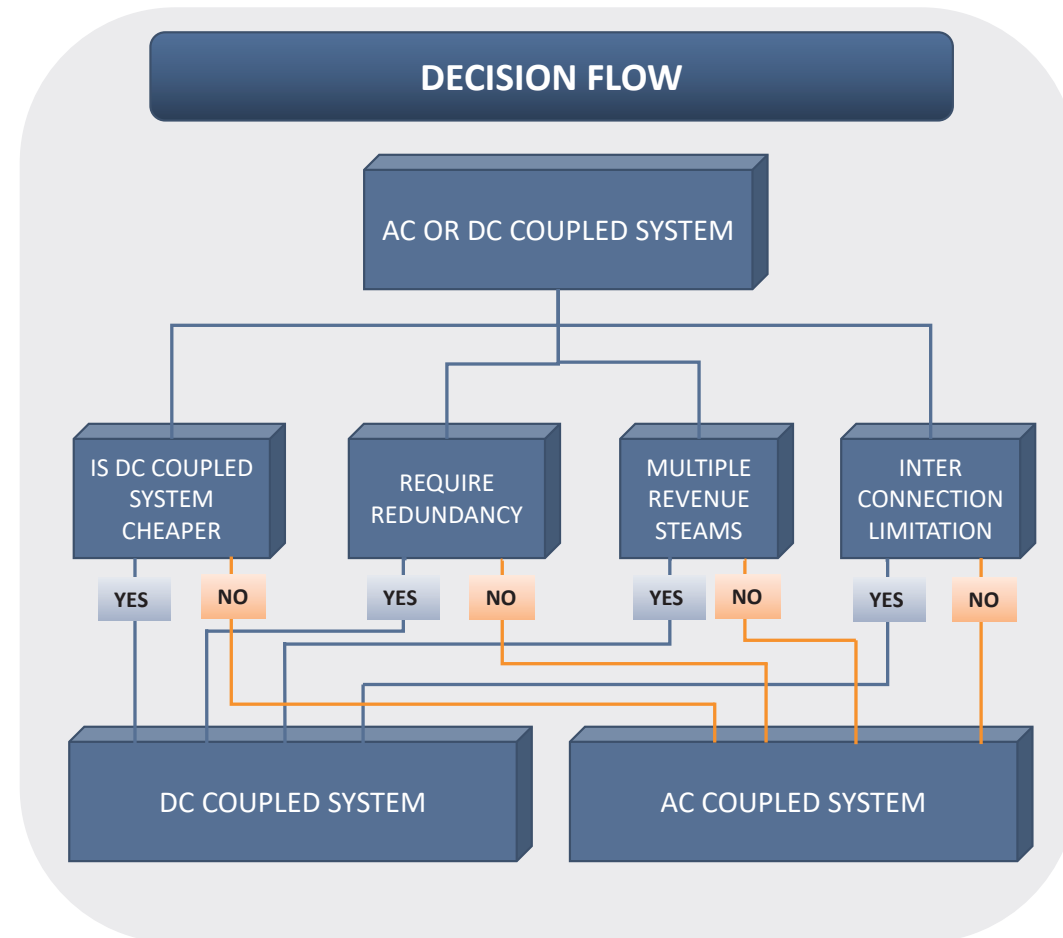


# SUMMARY

There is no clear answer whether DC coupled system is outright better than AC coupled system

It depends on the project needs and project owner objectives.

Solar plus Storage is evolving technology with its own set of challenges. Project owner must address product concerns with solution provider





# GEMINI SOLAR

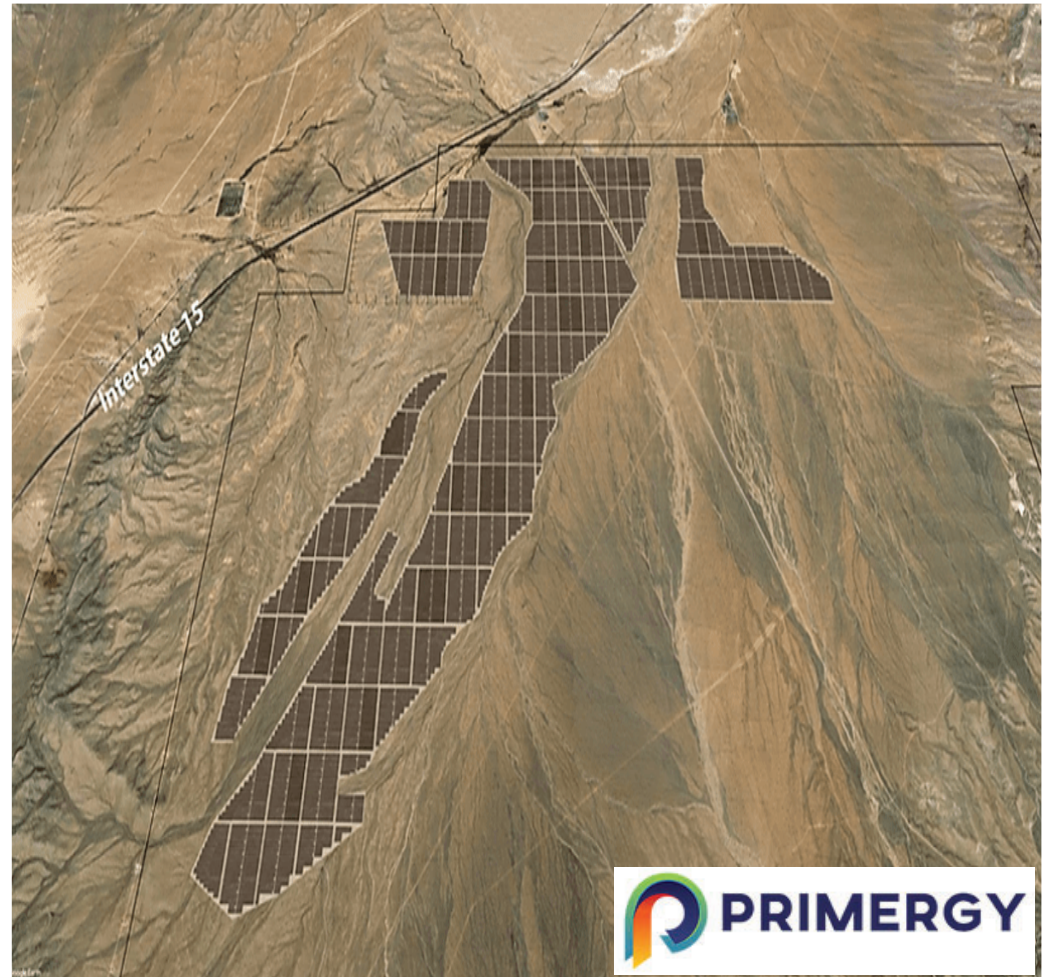
690 MW<sub>AC</sub>  
SOLAR

> 5000  
ACRES

380 MW<sub>AC</sub>  
ENERGY  
STORAGE

DC  
COUPLED  
PV +  
ENERGY  
STORAGE

<https://primergysolar.com/>  
<https://primerygemini.com/>



## **BROADER MARKET TRENDS**

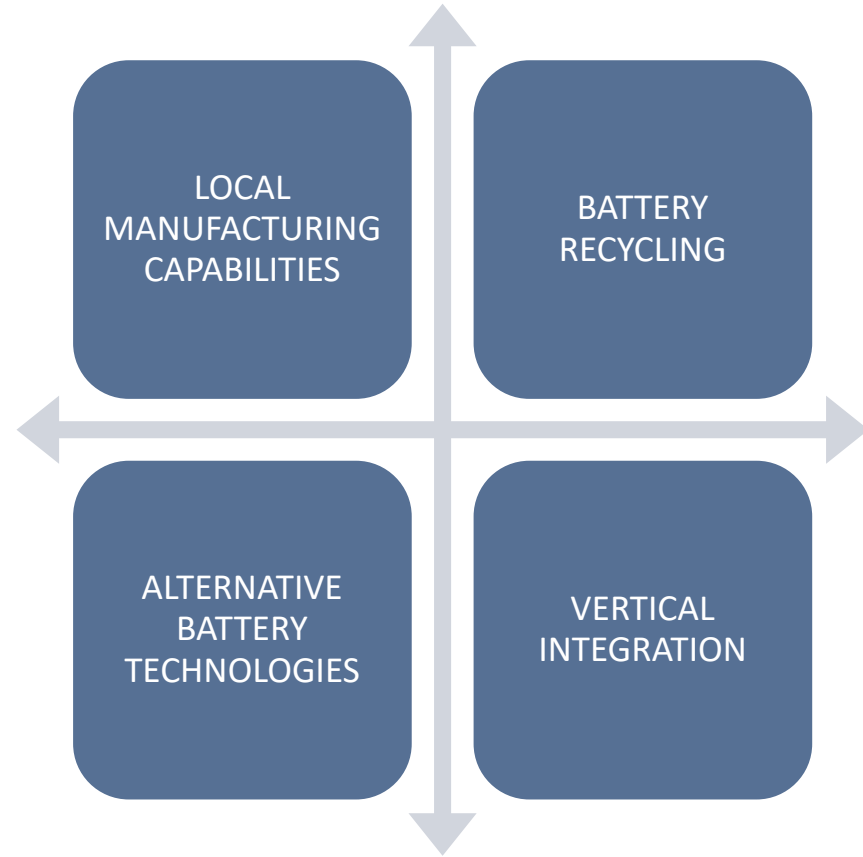
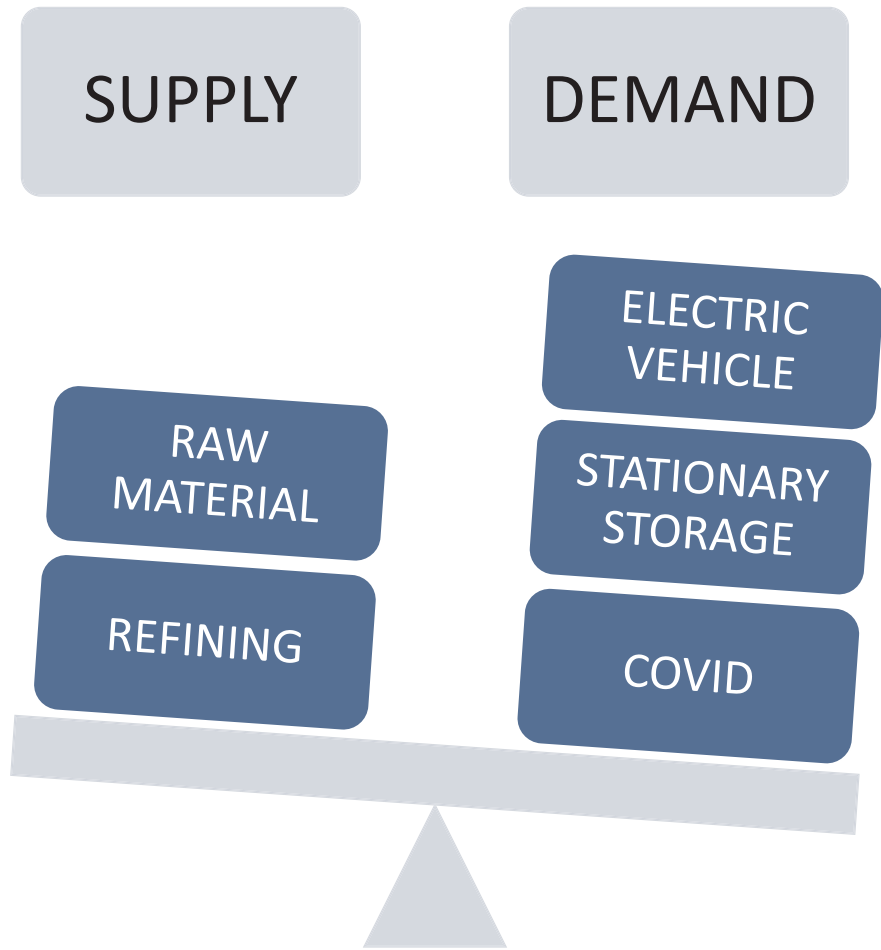
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# SUPPLY CHAIN ISSUES



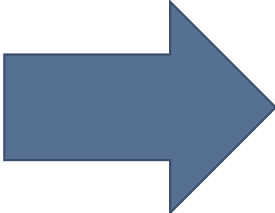
# MODULARIZATION



CATL ENERONE



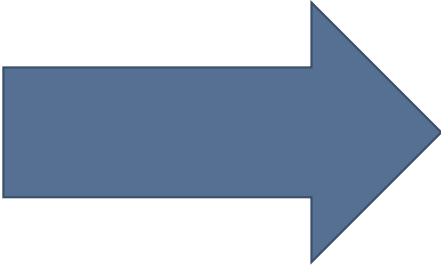
FLUENCE GRIDSTACK



15' – 20' fully packaged container

# EPCS IN BESS INTEGRATION

BESS INTEGRATORS: TODAY



BESS INTEGRATORS: IN FUTURE



THANK YOU