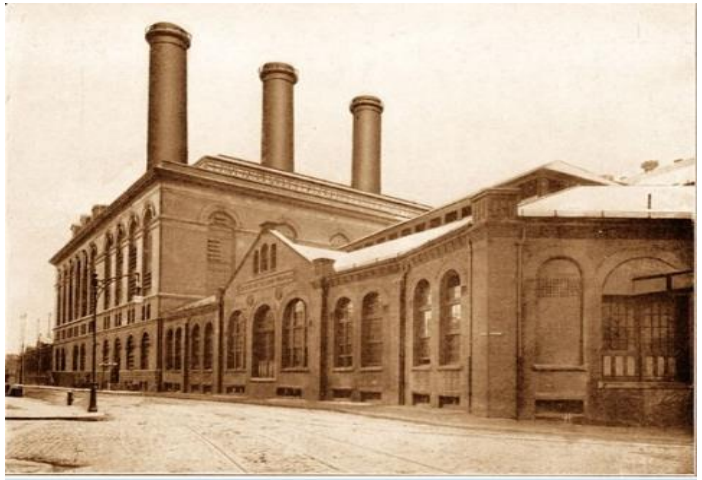
**Brian T. Patterson**
President
EMerge Alliance

# Opening the Door to Direct Current Power Systems

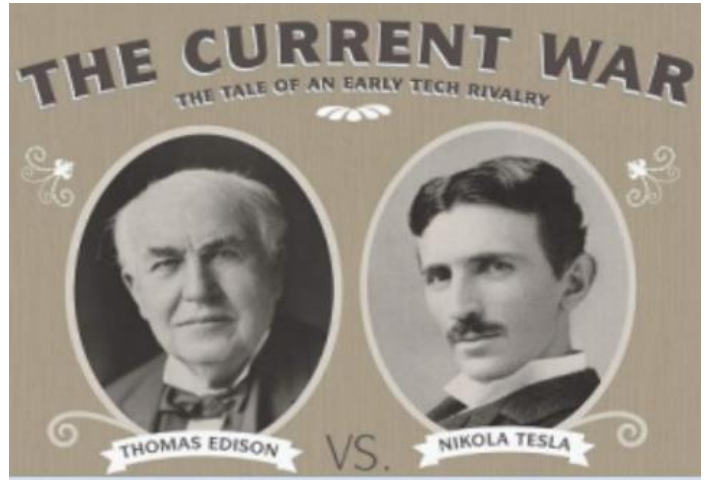
## Evolution or Revolution?


TODAY’S DIGITAL INFORMATION WORLD



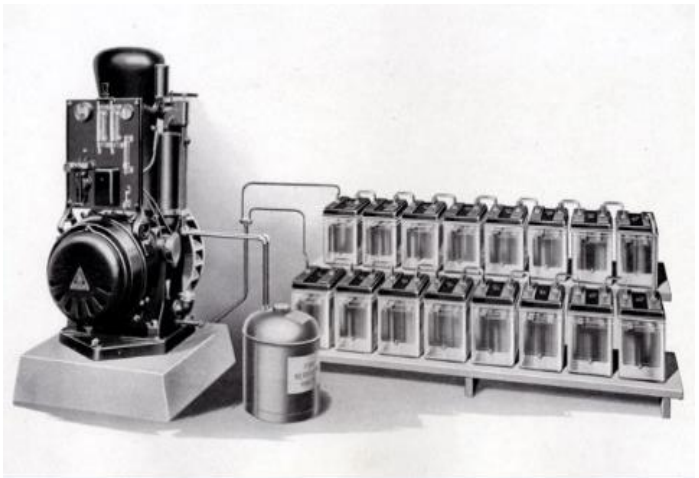
Thomas Edison's DC/Co-Generation Pearl Street Station—NY, NY.—1882

# In the beginning…




The Battle of the Currents—Edison vs. Tesla/Westinghouse –circa. 18

America's AC Powered Grid—East, West and Texas—1900—2016



Delco-Light 32Vdc Power Plant—Dayton Oh.—1916

# Eventually, things settled down…

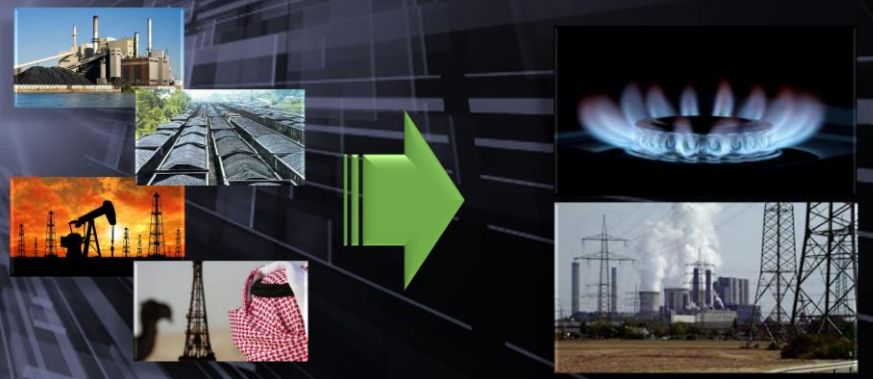
# So we could…

## Electric Infrastructure Issue #1


**Increasing Use of Electricity**

Despite Conservation Efforts – Use Grows at Double-Digit Rates

## Electric Infrastructure Issue #2



**Over Dependency on Fossil Fuel Sources**

Coal & Oil issues are leading to Increased Reliance on NG & Nuclear

# But more recently…

## Electric Infrastructure Issue #3

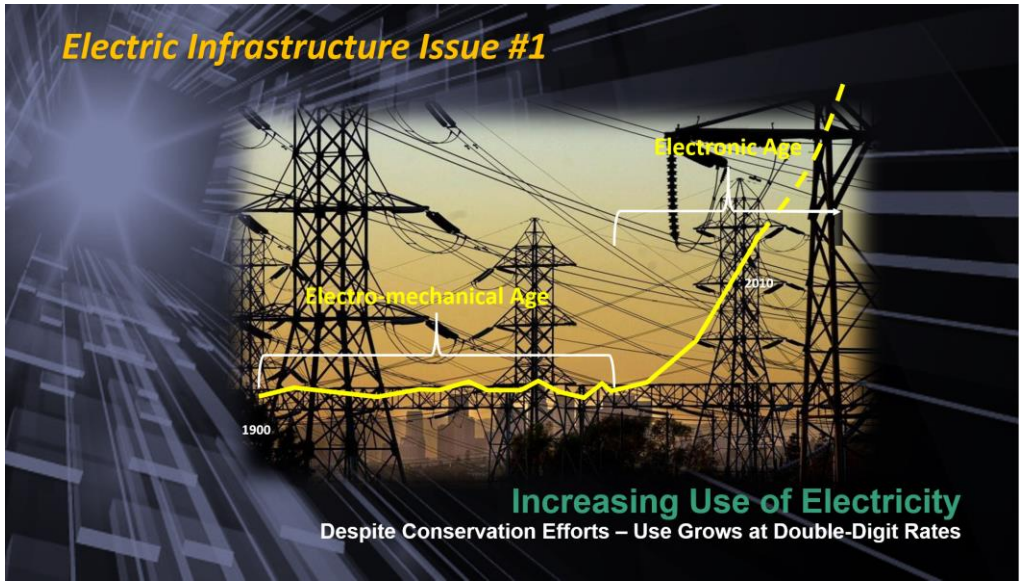

**Resistance to Expanding Centralized Infrastructure**

There are real & perceived problems with using public domains

## Electric Infrastructure Issue #4


**Growing Problem of Resiliency**

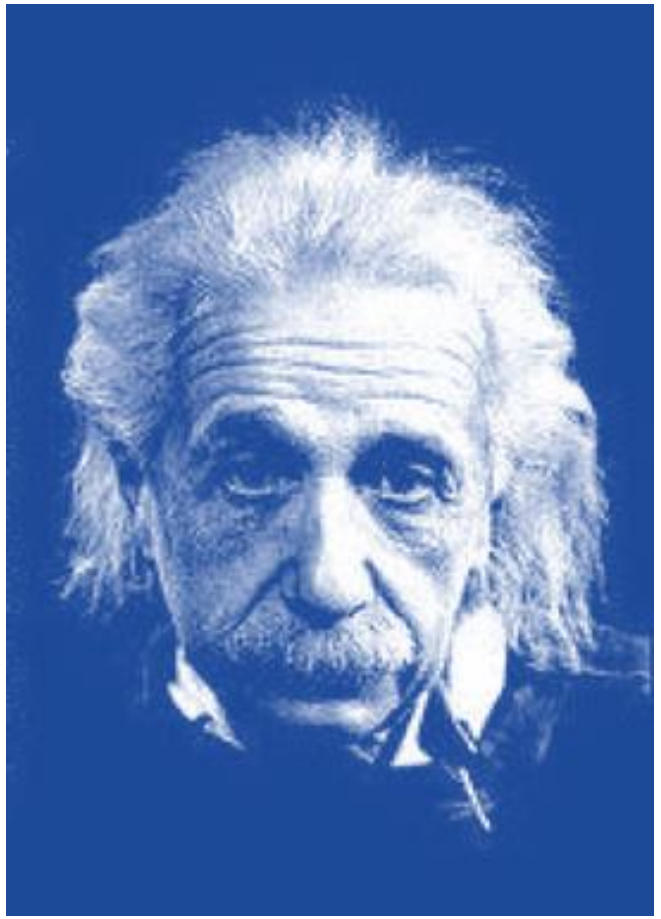
There are no easy answers for the existing grid





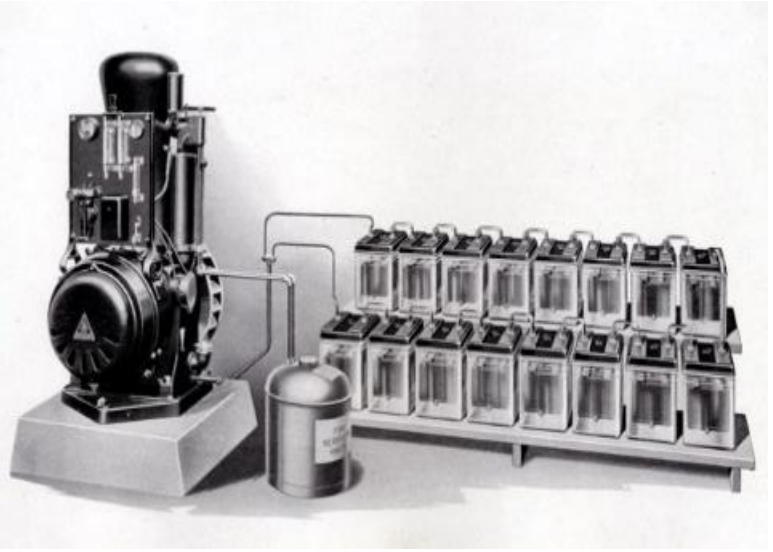
# we've been having some "issues"


“we cannot solve our problems with the same thinking we used when we created them”



AC Coupled Macrogrids

# So, can we take two old ideas…

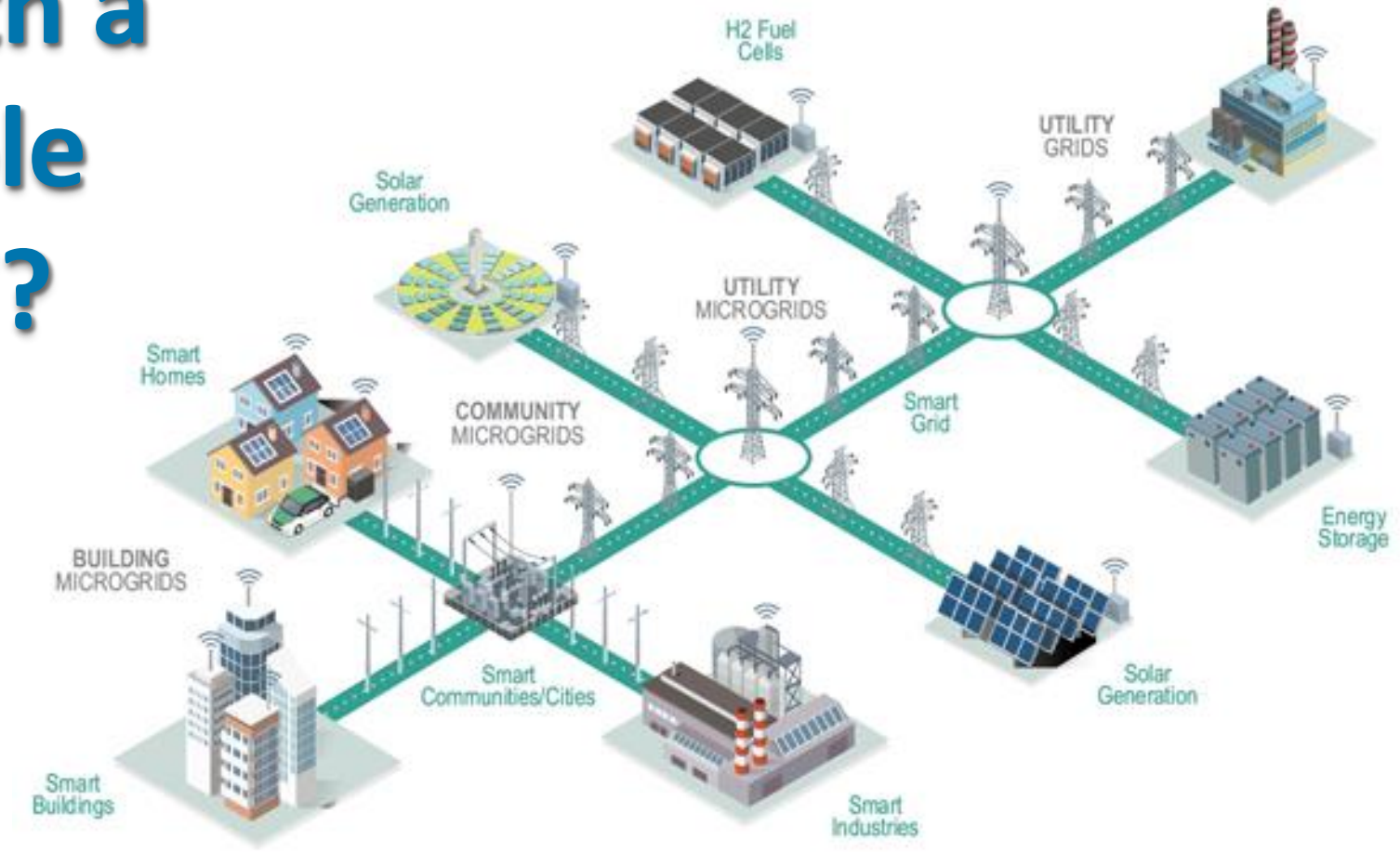


DC Coupled Microgrids

…add some ‘smarts’ & some new technology…

# …connect the old with the new…

# …and end up with a more sustainable "Grid of Grids"?




# The Grid of Grids evolution is well underway…

A terminal that contains processing power. Intelligent terminals include memory and a processor to perform special operations.

In contrast, a dumb terminal has no processing capabilities; it must rely entirely on the central computer.

# …as the Grid is getting “Smarter”…

# …dc coupled microgrids are evolving to help!

# Let’s see how…

# Microgrids are comprised of 5 major functions…

LOCAL SOURCES

ENERGY STORAGE

ENERGY MANAGEMENT

CIRCUIT UTILIZATION

LOCAL LOADS

LOCAL SOURCES

ENERGY STORAGE

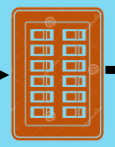
ENERGY MANAGEMENT

CIRCUIT UTILIZATION

LOCAL LOADS

UTILITY AC DISTRIBUTION GRID

AC Load Panel



AC Loads

MONITOR

CONTROLLER

CONVERTERS
AC-DC
DC-DC
DC-AC

INTERCONNECT

Solar PV

Wind

Grid Tied Solar and Wind

LOCAL SOURCES

ENERGY STORAGE

ENERGY MANAGEMENT

CIRCUIT UTILIZATION

LOCAL LOADS

UTILITY AC DISTRIBUTION GRID

AC Convenience Load Panel

AC Convenience Loads

AC Critical Loads

MONITOR

CONTROLLER

CONVERTERS
AC-DC
DC-DC
DC-AC

INTERCONNECT

Solar PV

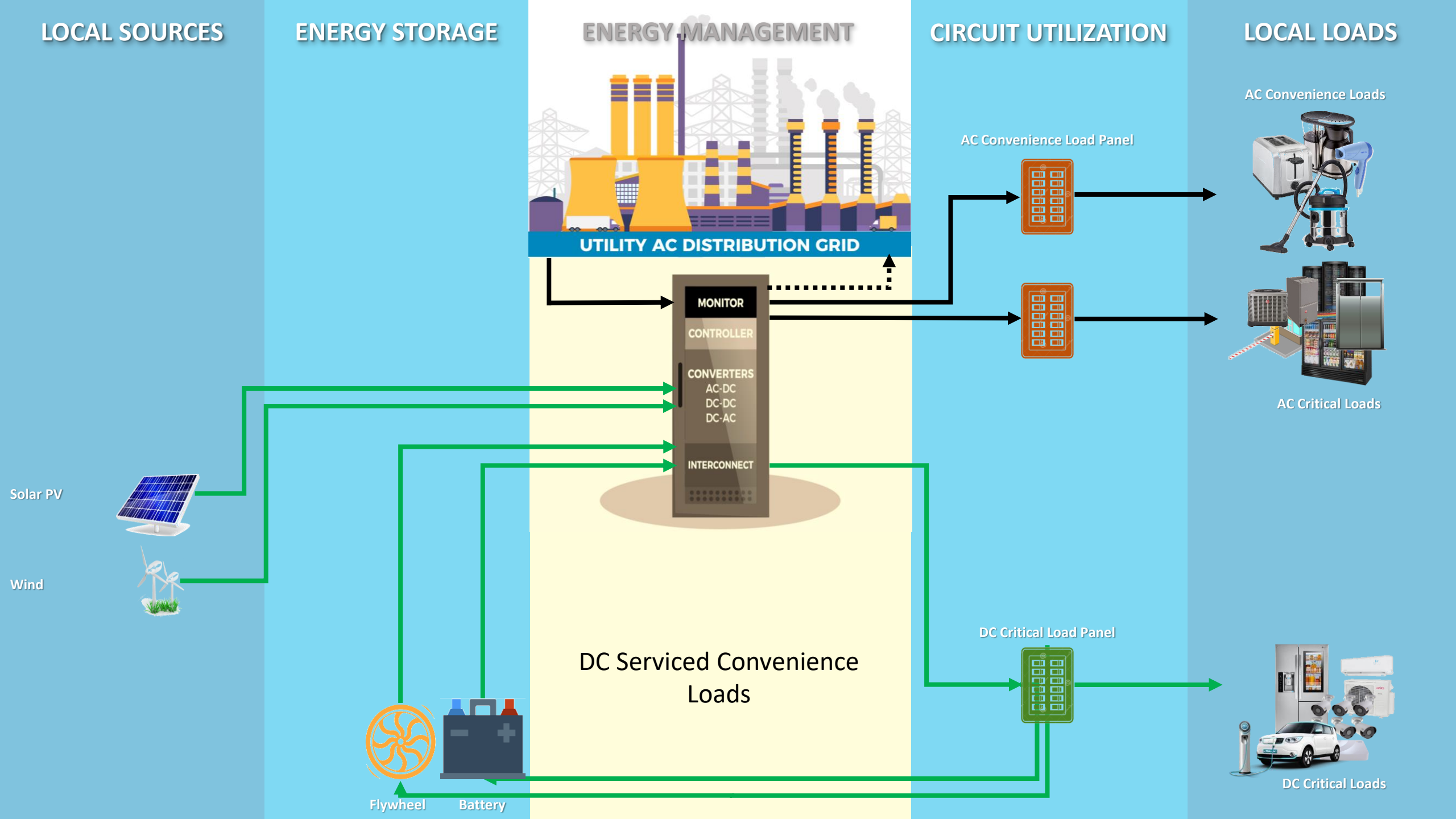
Wind

DC Critical Load Panel

Solar/Wind With DC Coupled Storage

Flywheel

Battery


LOCAL SOURCES
ENERGY STORAGE
ENERGY MANAGEMENT
CIRCUIT UTILIZATION
LOCAL LOADS
AC Convenience Loads
AC Convenience Load Panel
UTILITY AC DISTRIBUTION GRID
MONITOR
CONTROLLER
CONVERTERS
AC-DC
DC-DC
DC-AC
INTERCONNECT
AC Critical Loads
Solar PV
Wind
DC Critical Load Panel
DC Serviced Convenience Loads
Flywheel
Battery
DC Critical Loads

LOCAL SOURCES

ENERGY STORAGE

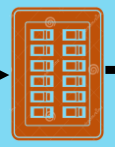
ENERGY MANAGEMENT

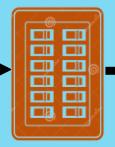
CIRCUIT UTILIZATION

LOCAL LOADS

AC Convenience Loads

AC Convenience Load Panel





UTILITY AC DISTRIBUTION GRID

MONITOR

CONTROLLER

CONVERTERS
AC-DC
DC-DC
DC-AC

INTERCONNECT

AC Critical Loads

Solar PV

Wind

DC Convenience Load Panel

DC Convenience Loads

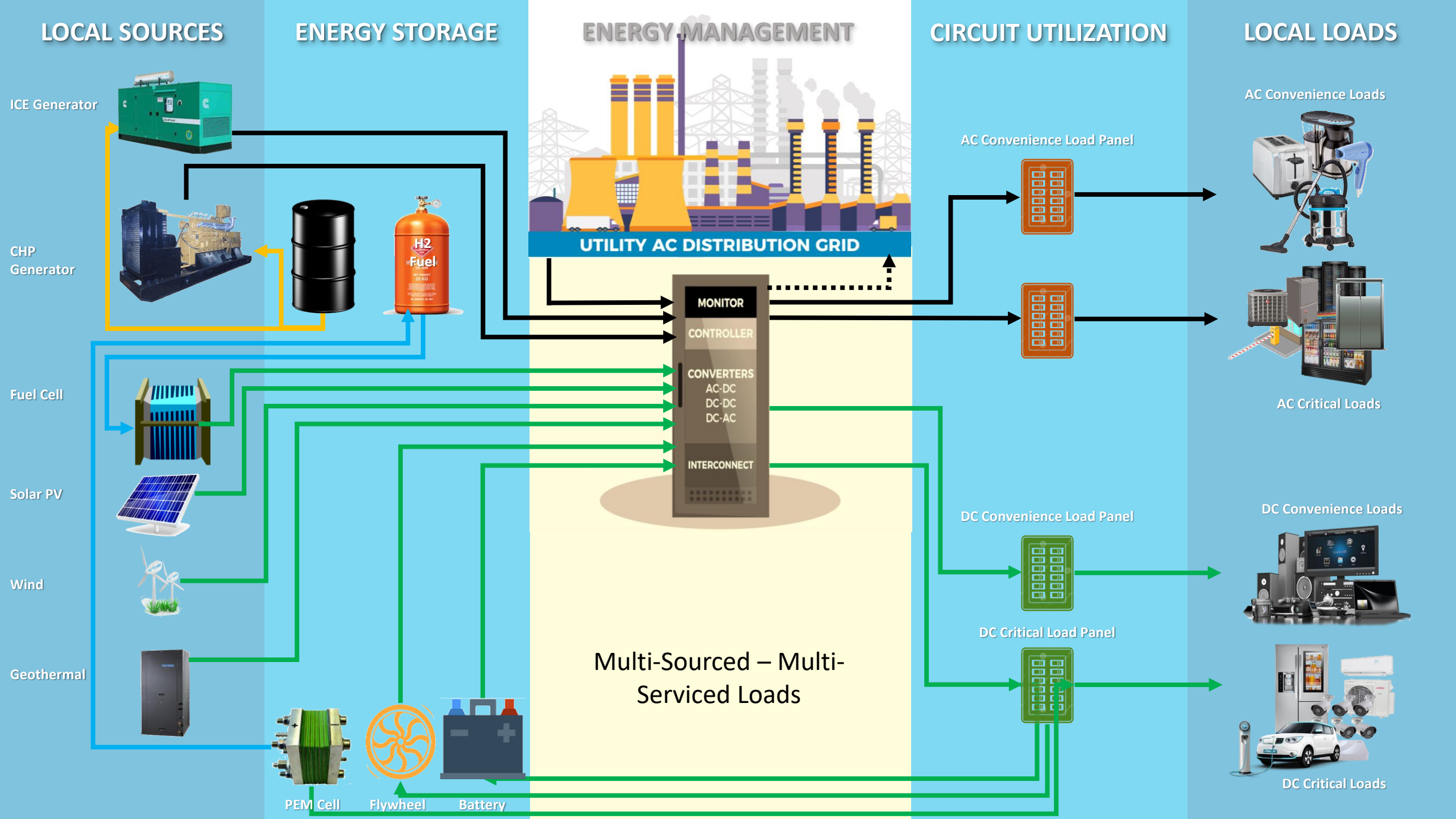
DC Critical Load Panel

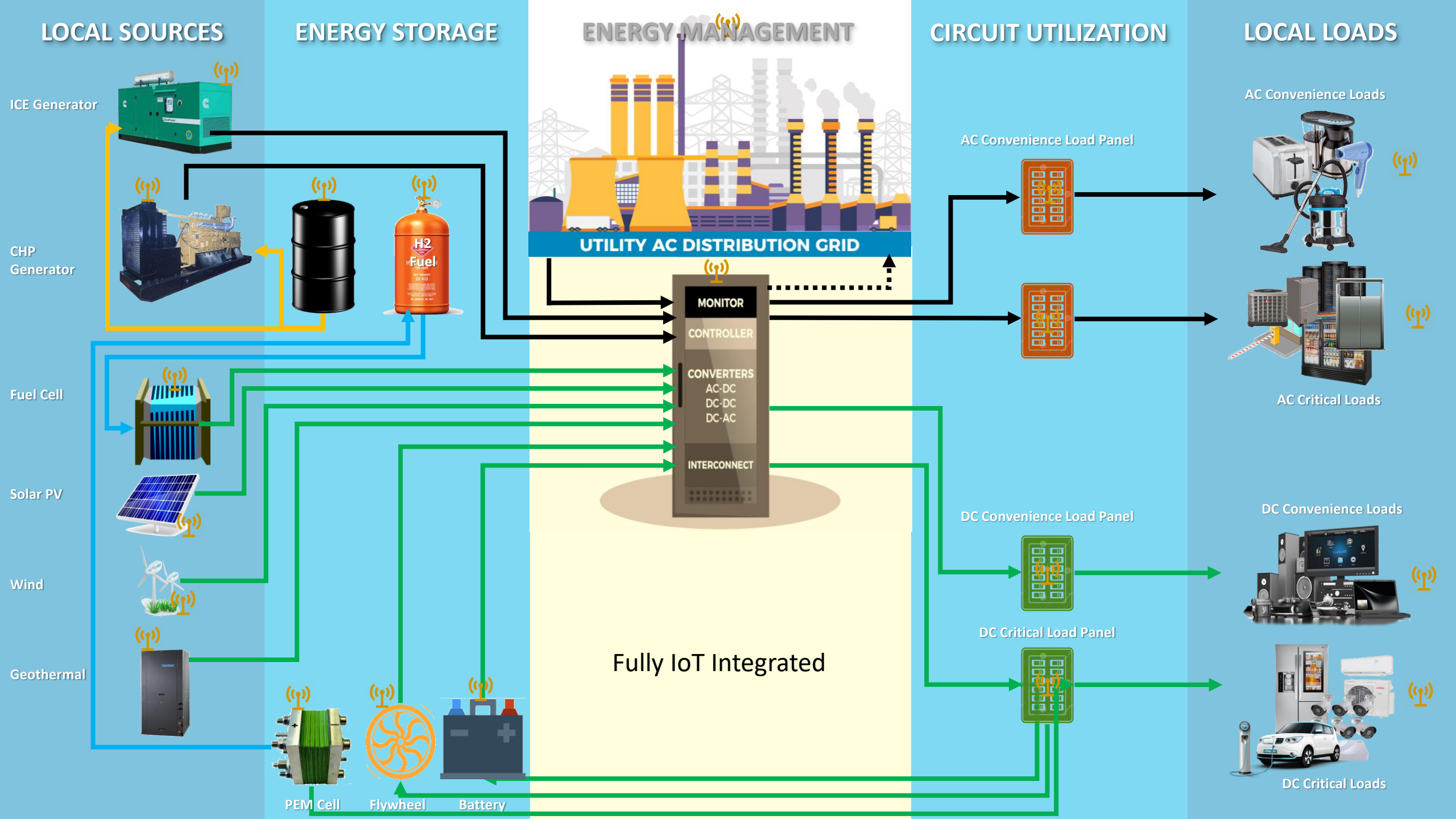
DC Serviced Convenience &
Critical Loads

Flywheel

Battery

DC Critical Loads


LOCAL SOURCES
ENERGY STORAGE
ENERGY MANAGEMENT
CIRCUIT UTILIZATION
LOCAL LOADS
ICE Generator
CHP Generator
Fuel Cell
Solar PV
Wind
Geothermal
H2 Fuel
UTILITY AC DISTRIBUTION GRID
MONITOR
CONTROLLER
CONVERTERS
AC-DC
DC-DC
DC-AC
INTERCONNECT
AC Convenience Load Panel
DC Convenience Load Panel
DC Critical Load Panel
AC Convenience Loads
AC Critical Loads
DC Convenience Loads
DC Critical Loads
PEM Cell
Flywheel
Battery
Multi-Sourced – Multi-Serviced Loads


LOCAL SOURCES
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Wind
Geothermal
H2 Fuel
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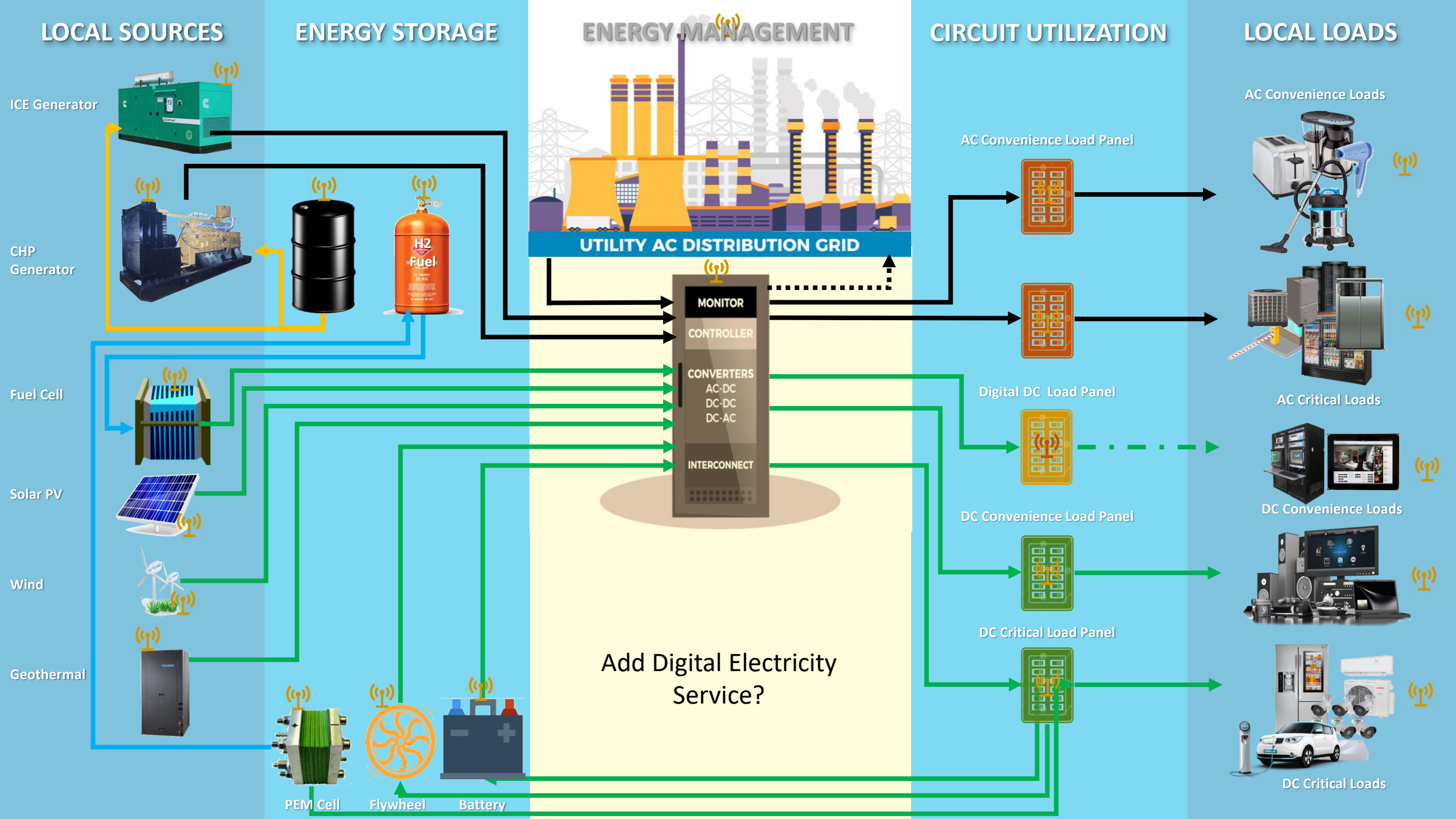
MONITOR
CONTROLLER
CONVERTERS
AC-DC
DC-DC
DC-AC
INTERCONNECT
AC Convenience Load Panel
DC Convenience Load Panel
DC Critical Load Panel
AC Convenience Loads
AC Critical Loads
DC Convenience Loads
DC Critical Loads
PEM Cell
Flywheel
Battery
Fully IoT Integrated


LOCAL SOURCES
ENERGY STORAGE
ENERGY MANAGEMENT
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LOCAL LOADS
ICE Generator
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UTILITY AC DISTRIBUTION GRID
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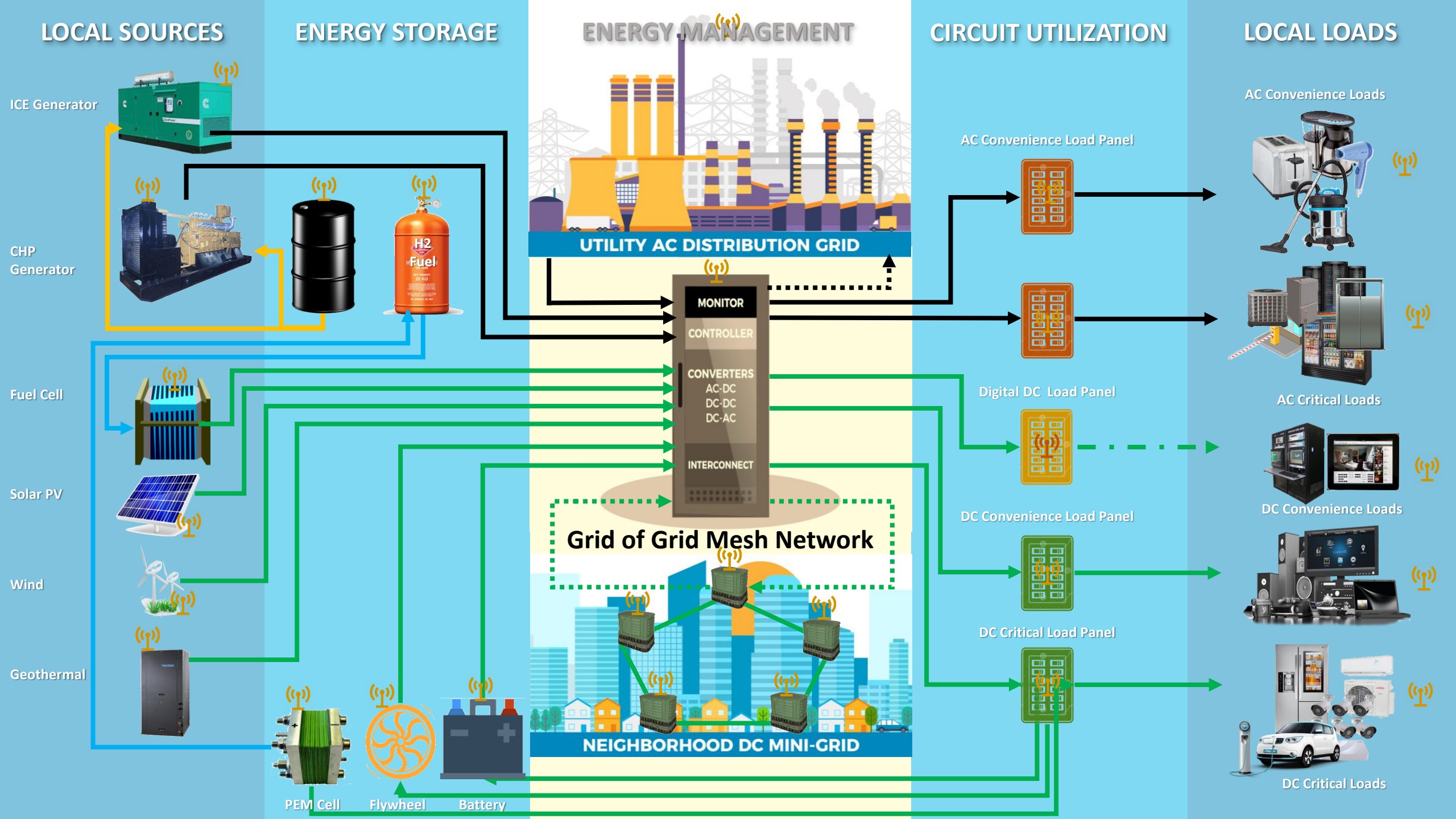
CONTROLLER
CONVERTERS
AC-DC
DC-DC
DC-AC
INTERCONNECT
AC Convenience Load Panel
Digital DC Load Panel
DC Convenience Load Panel
DC Critical Load Panel
AC Convenience Loads
AC Critical Loads
DC Convenience Loads
DC Critical Loads
PEM Cell
Flywheel
Battery
Add Digital Electricity Service?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Battery
UTILITY AC DISTRIBUTION GRID
MONITOR
CONTROLLER
CONVERTERS
AC-DC
DC-DC
DC-AC
INTERCONNECT
Grid of Grid Mesh Network
NEIGHBORHOOD DC MINI-GRID
AC Convenience Load Panel
Digital DC Load Panel
DC Convenience Load Panel
DC Critical Load Panel
AC Convenience Loads
AC Critical Loads
DC Convenience Loads
DC Critical Loads

# Key Attributes of the Grid of Grids:

- Most power is generated at the fringe
- New generation, storage and load is natively direct current.
- Non-synchronous dc-coupling at the local level minimizes disruptive impact of distributed resource integration
- Self-configuring mesh topology avoids linear dynamic failures
- Semi-autonomous distributed control supports a tiered transactional management structure
- Local enables “energy as a service” differentiation and capability