Rethink the delivery of electricity

Distributed Energy Resources:

Energy Systems Integration 101
NREL
July 23, 2014

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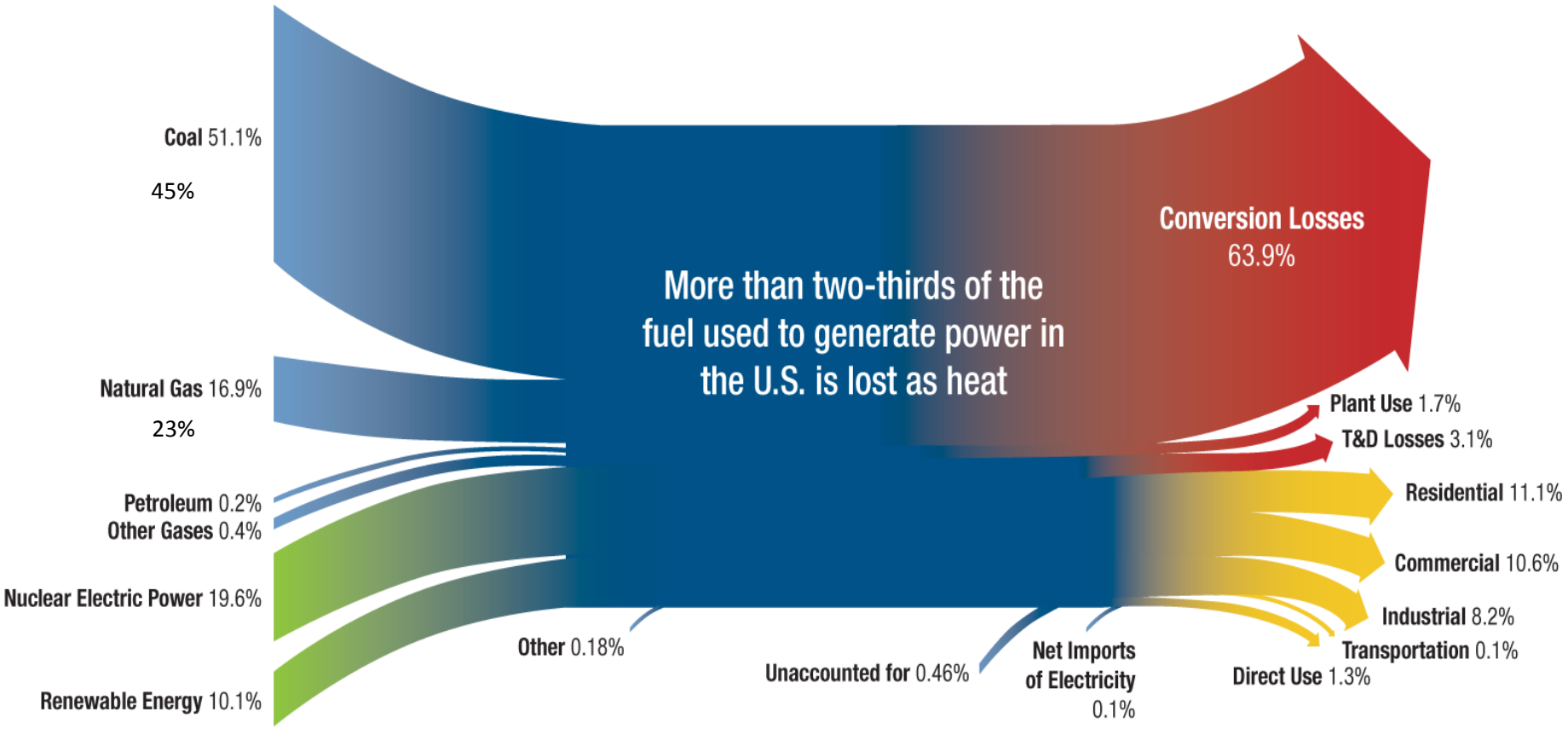
University of Wisconsin

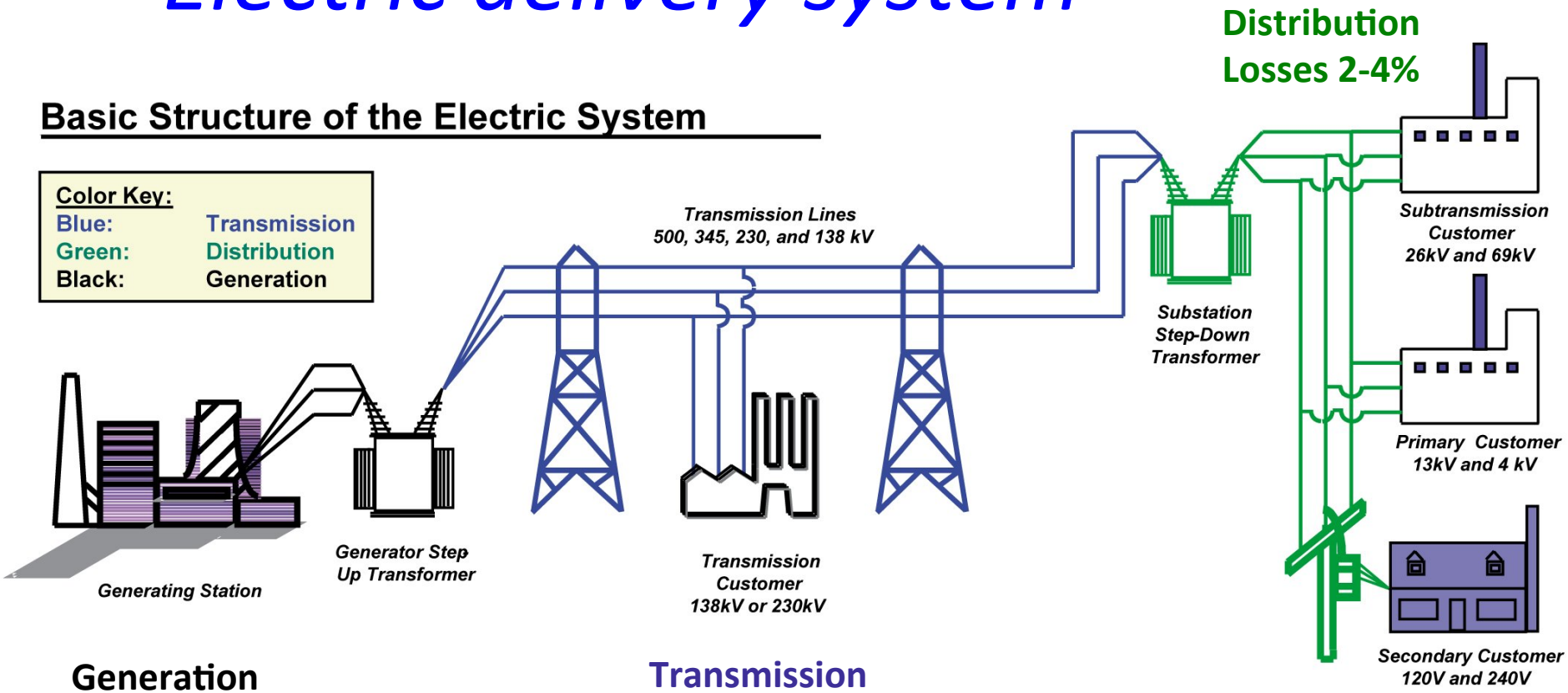
Rethink the delivery of electricity

- Better use of energy sources (electrical & thermal)
- Lower emissions
- Potential of Distributed Energy Resources

Over Two Thirds of the Fuel Used to Generate Electric Power in the United States Is Lost as Heat



Electric delivery system



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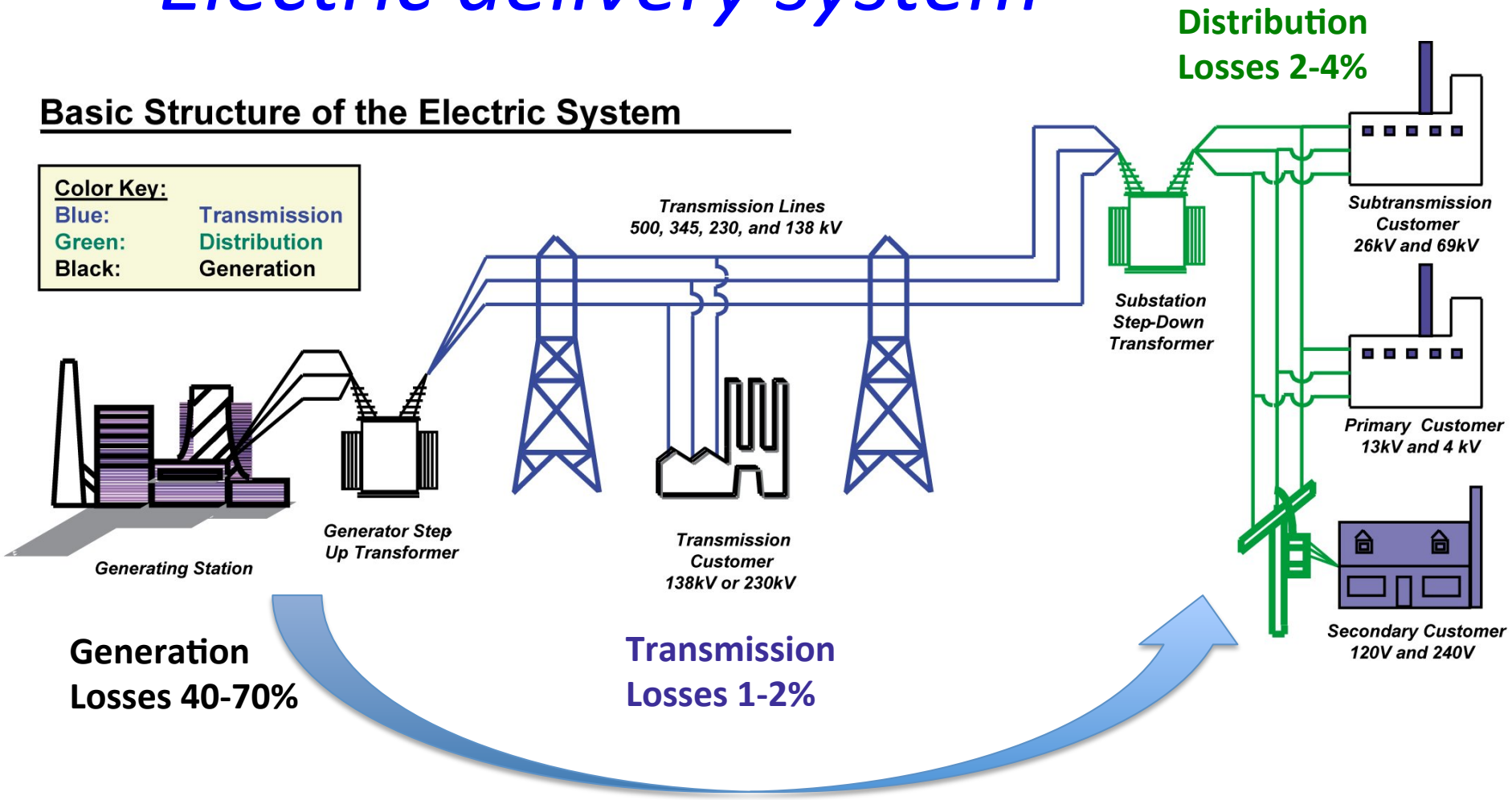
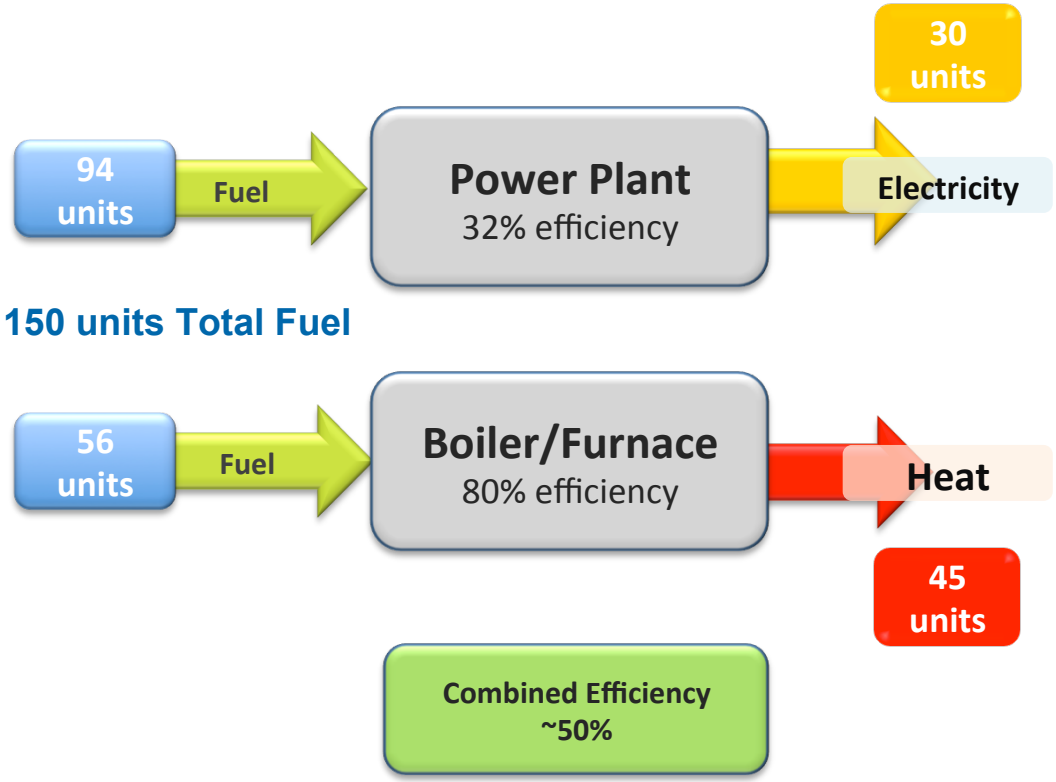


Move generation closer to the load centers to use the *waste heat* and *provide local reliably*!

CHP Recaptures Much of that Heat, Increasing Overall Efficiency of Energy Services



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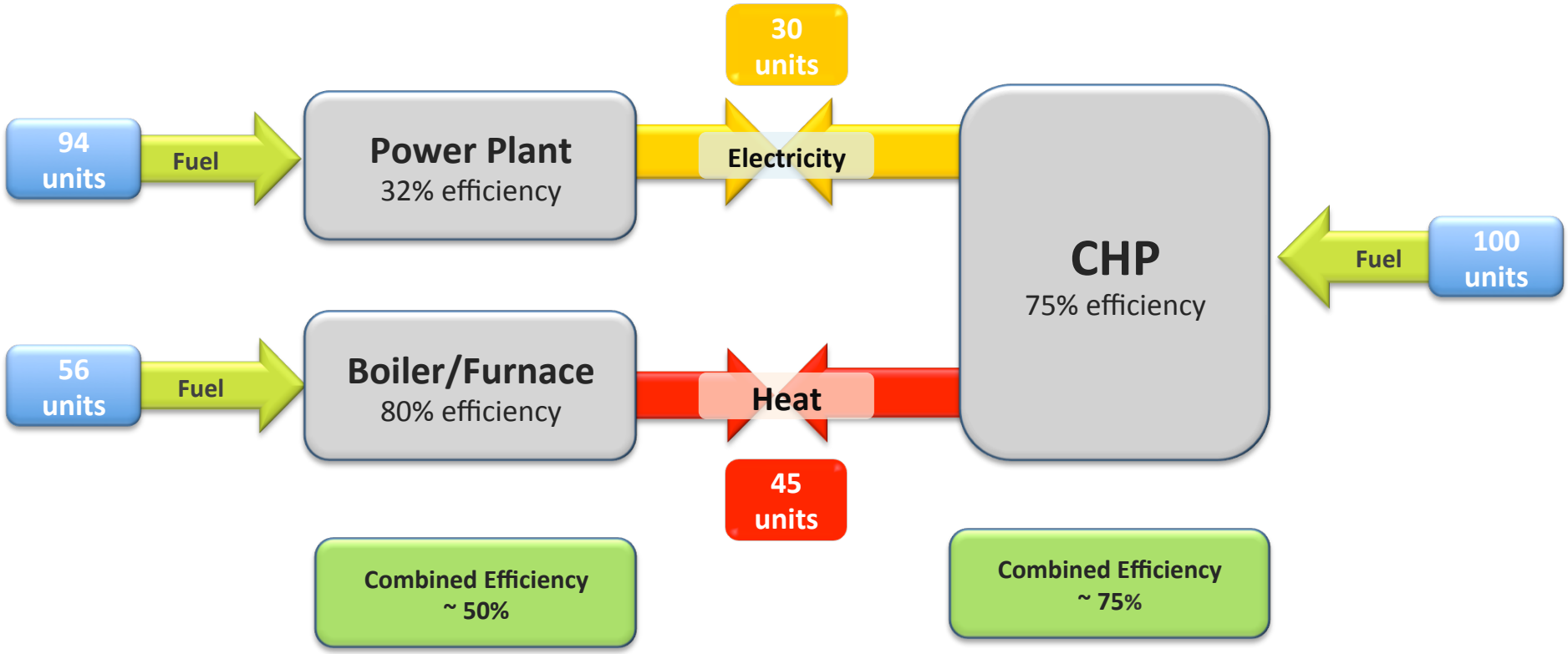
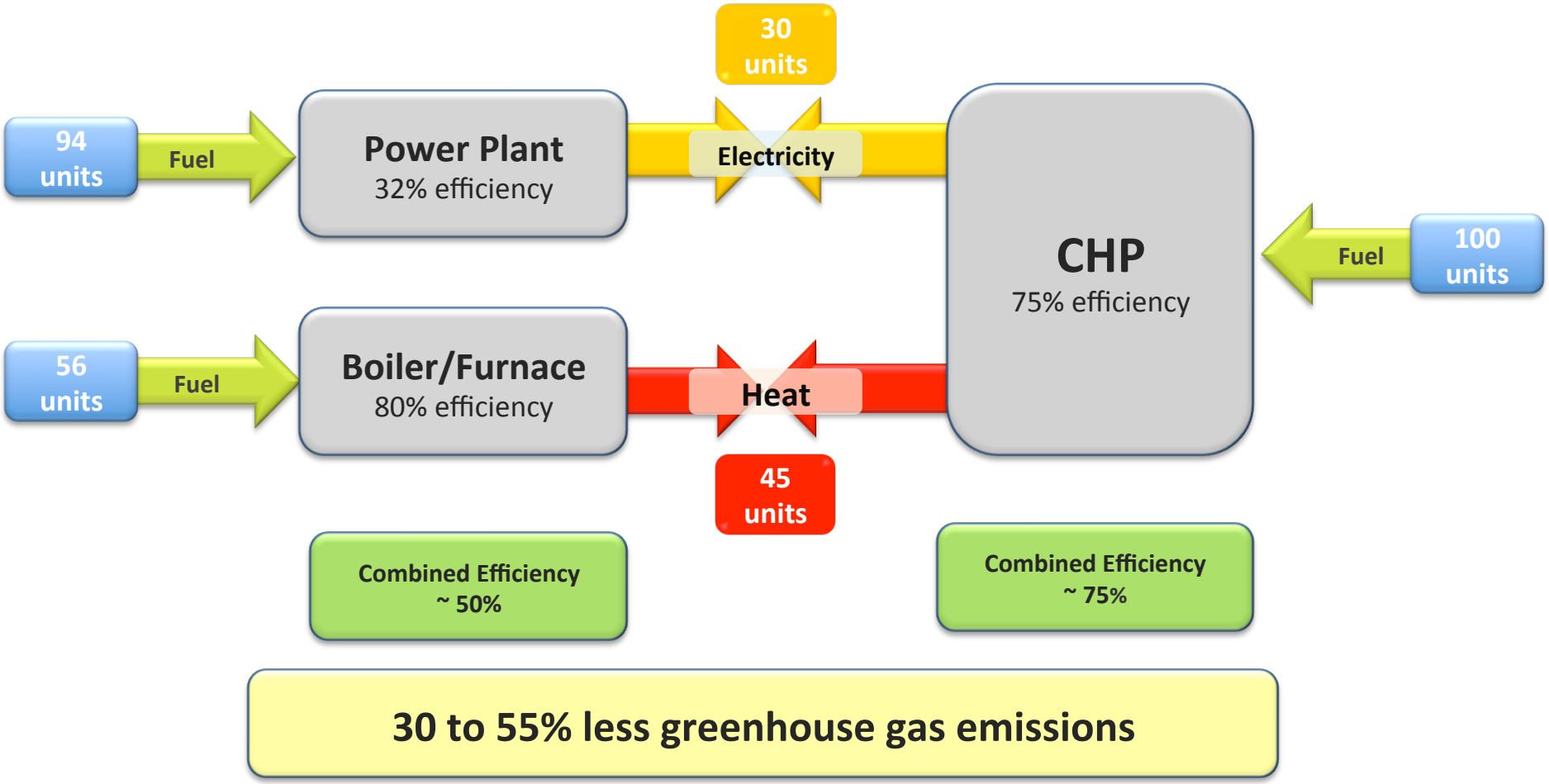
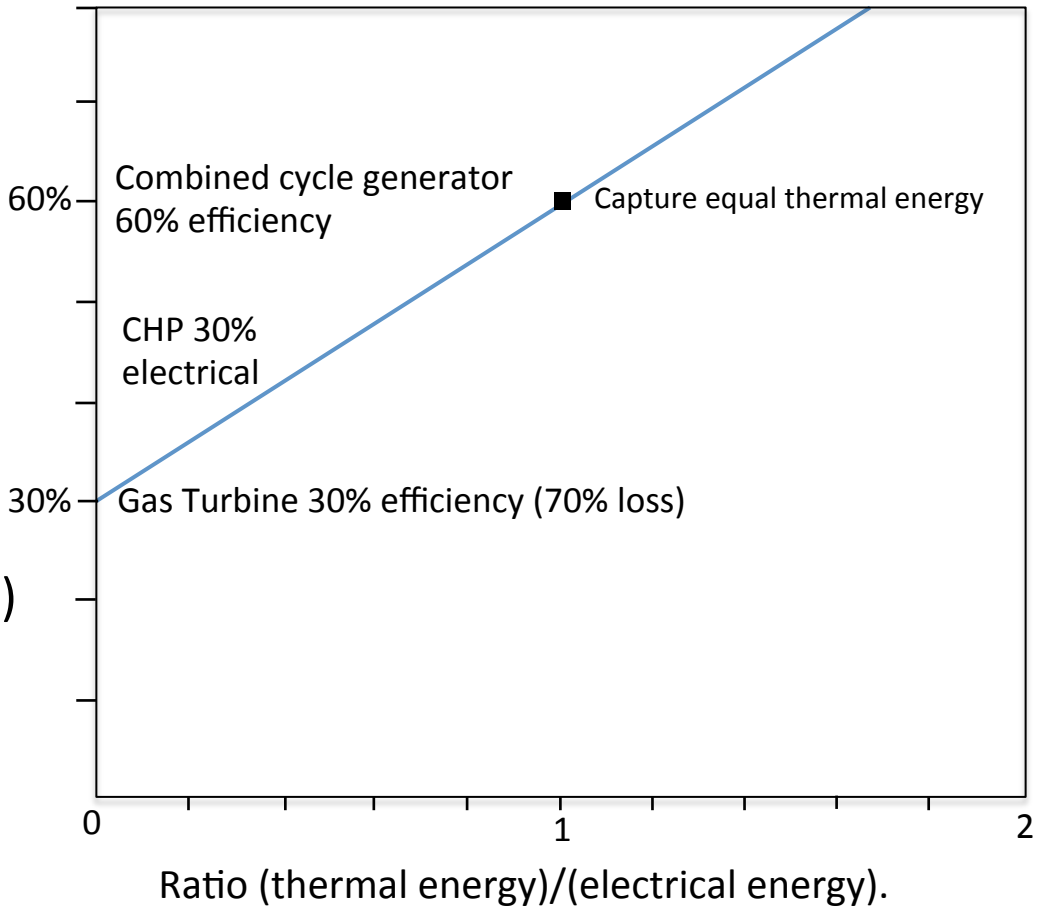


…. and Reduces Greenhouse Gas Emissions



Combined Cooling Heat and Power (CCHP)

- Unlike electricity, heat cannot be efficiently transmitted over long distances
- Heat can be used in space heating, absorption chillers, desiccant dehumidification, water heating, process heat.
- Total efficiency (electric + heat) increases as heat demand increases
- Most cases this ratio is not fixed!



Rethink the delivery of electricity

Better use of energy sources-

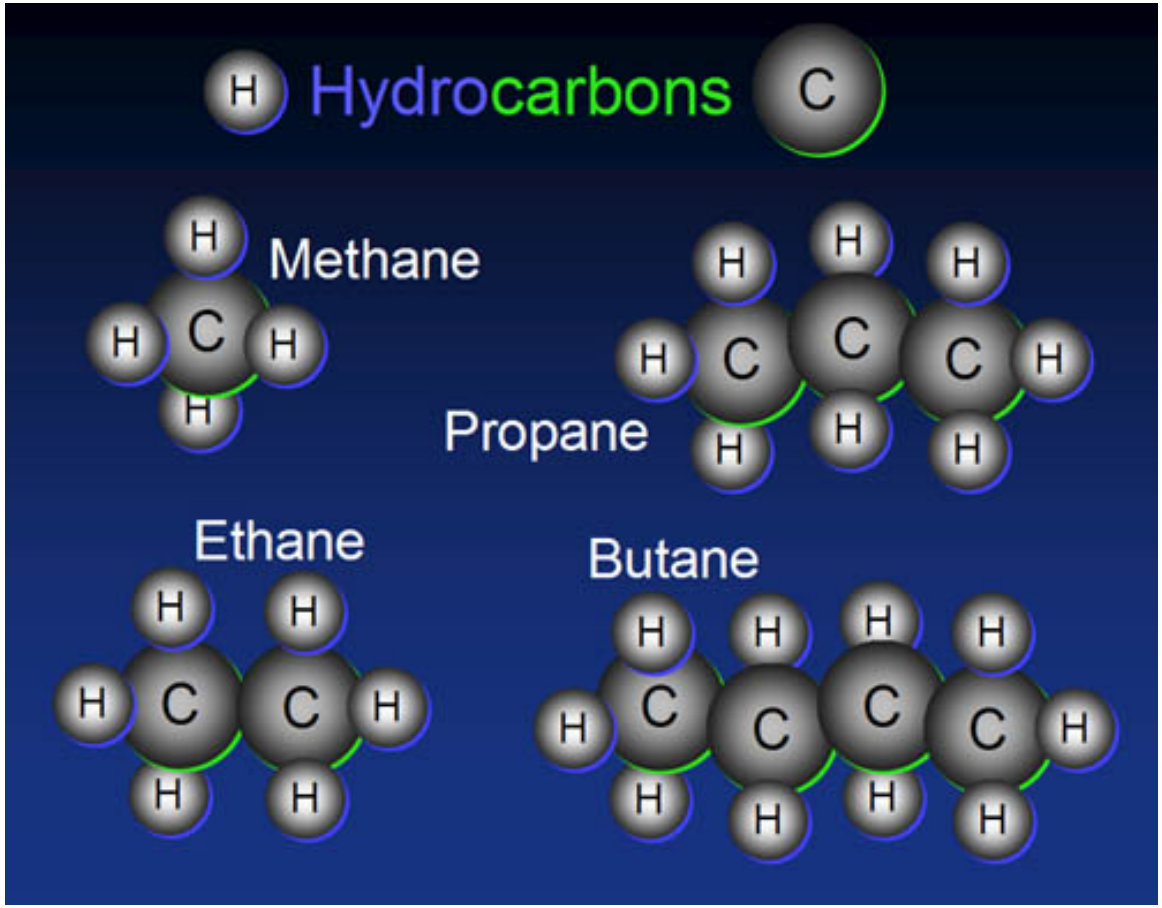
- ✓ CCHP Increases overall efficiency of energy services & has less greenhouse gas emissions

Lower emissions

- Look at hydrocarbons impact on carbon emissions

Potential of Distributed Energy Resources

Critical: Ratio of Carbon to Hydrogen



Methane $CH_4 + 2O_2 > CO_2 + 2H_2O$

CO_2 from Types of fuel

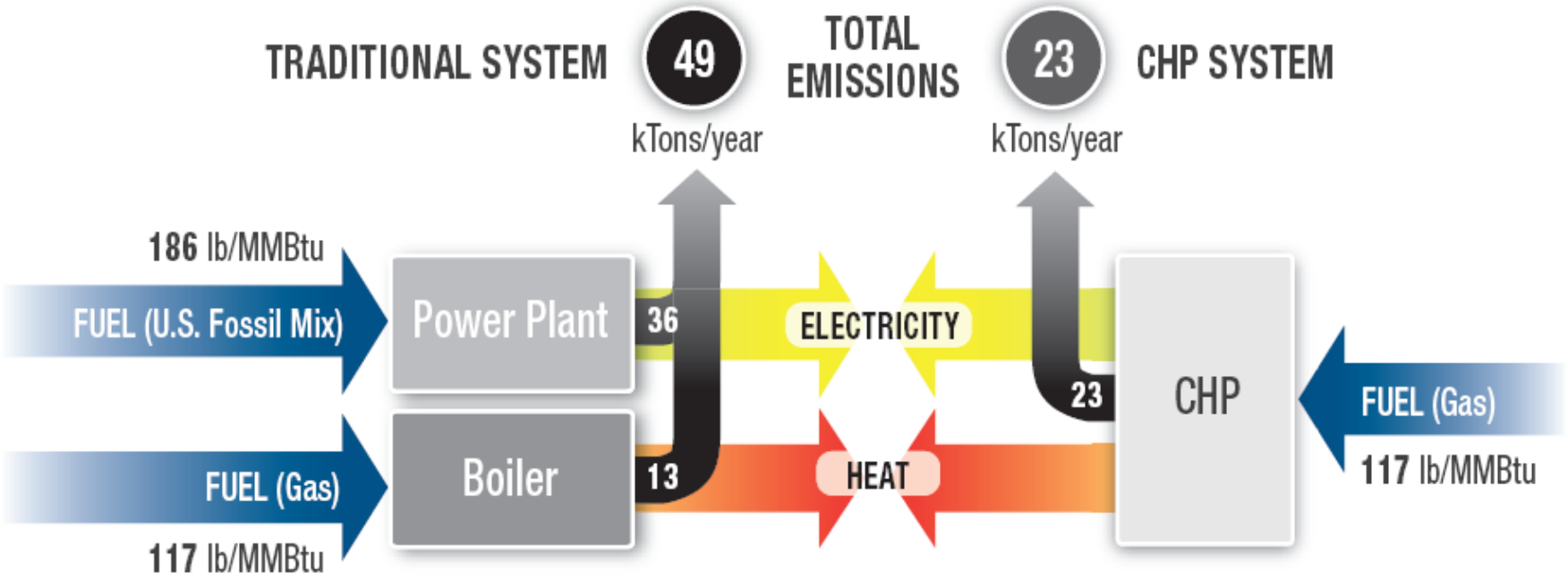
Combustion of Methane (Natural gas)

$CH_4 + 2O_2 > CO_2 + 2H_2O$

Fuel	H/C Ratio	Energy Content (kJ/g)	CO2 Released (mol/10^3kJ)
Hydrogen	…….	120	…….
Methane	4/1	51.6	1.2
Ethanol	3/1	27.3	1.6 (+33%)
Petroleum	2/1	43.6	1.6 (+33%)
Coal	1/1	39.3	2.0 (+66%)

Our Environmental Future: CHP and Gas

Impact on Carbon Emissions



Example of the CO_2 savings potential of CHP based on a 5 MW gas turbine CHP system with 75% overall efficiency operating at 8,500 hours per year providing steam and power on-site compared to separate heat and power comprised of an 80% efficient on-site natural gas boiler and average fossil based electricity generation with 7% T&D losses.

Source: http://www.chpcentermw.org/pdfs/ORNL_Report_Dec2008.pdf

Rethink the delivery of electricity

Better use of energy sources-

- ✓ CCHP Increases overall efficiency of energy services & has less greenhouse gas emissions

Lower Carbon emissions

- ✓ Bio-gas/methane/natural gas have minimum carbon emissions

Potential of Distributed Energy Resources

Distributed Energy Resources

Removes transmission losses and helps use waste heat

Dispatchable Sources (10kW ~ 3 MW)

- Internal combustion-engine generator
- Small gas turbines generators
- Microturbines
- Fuel cells

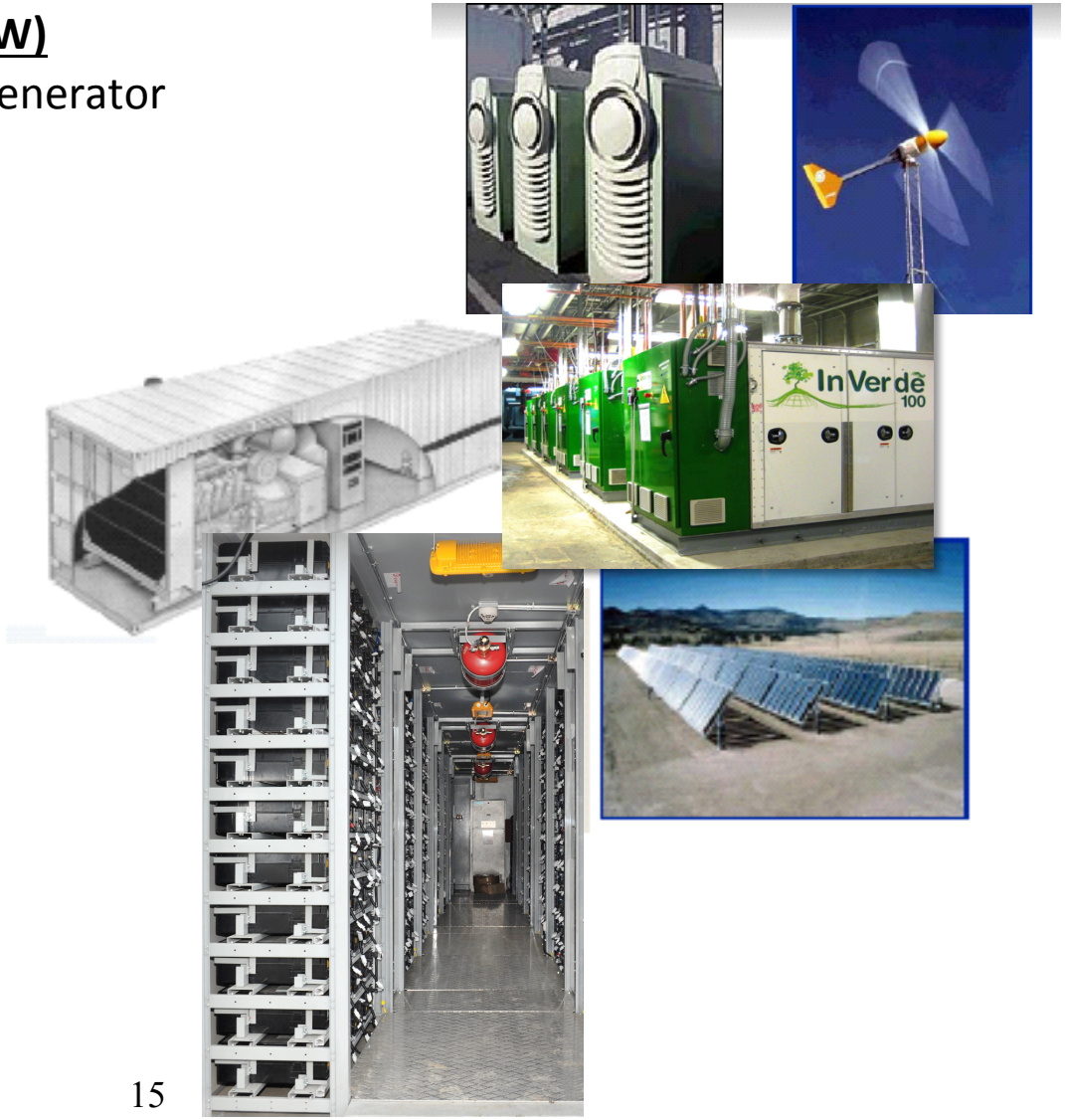
Potential use of waste heat

Intermittent Sources

- Wind turbines
- Photovoltaic

Storage

- Batteries, Ultra-capacitors
- Fly-wheels
- Electrical vehicles?



Natural Gas Combustion Turbine (peaking plant)

- Ratings 500-10,000 kWs
- $N0_x$ (lb/kWh) 0.0012
- CO_2 (lb/kWh) 1.15
- Efficiency 30%

Ramp rate 10%-90% ~12 mins

Micro turbine

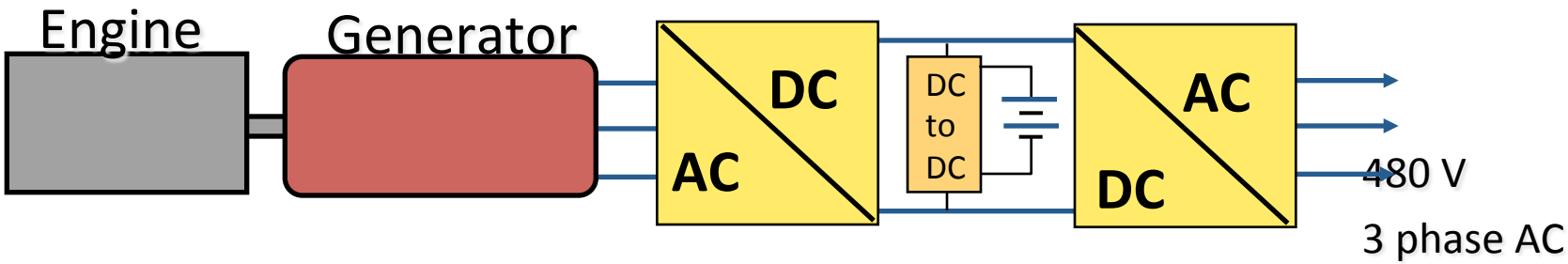
Efficiency 30%

Air foil bearings

Operation speed 90,000-100,000 RPMs

Ramp rate 10% to 90 % ~12 sec

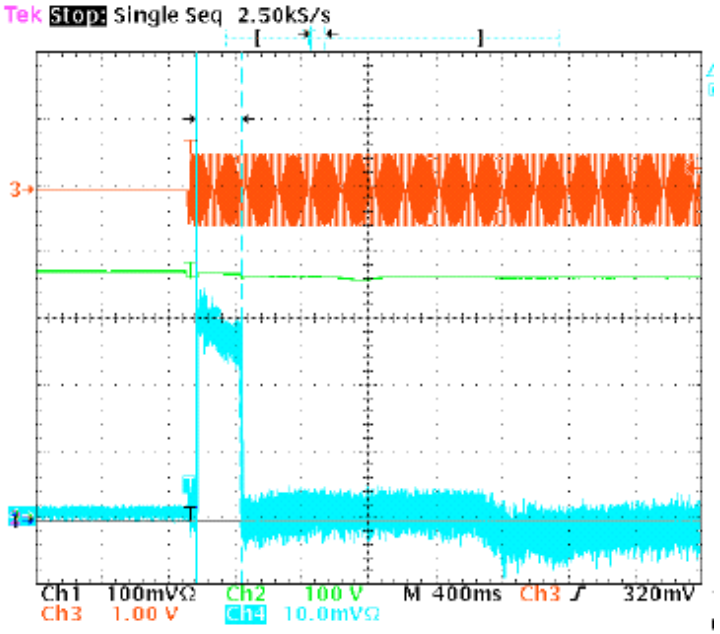
ICE with inverter interface

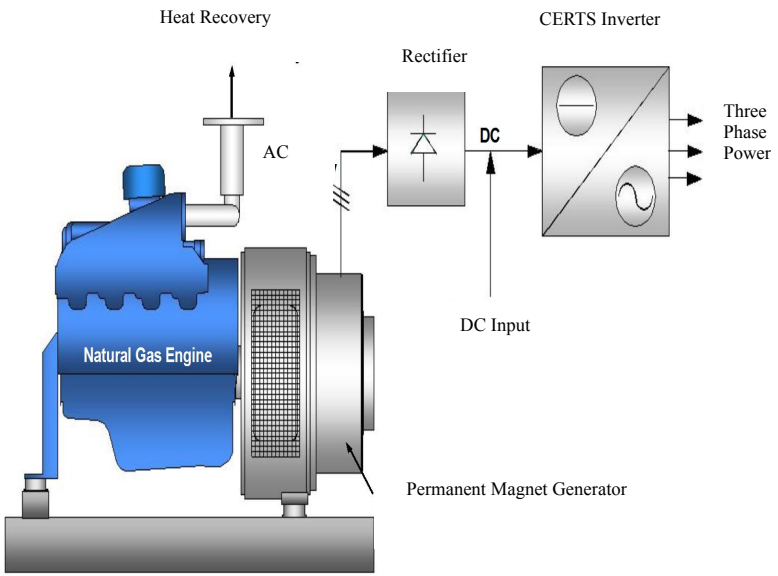


AC current

Dc voltage

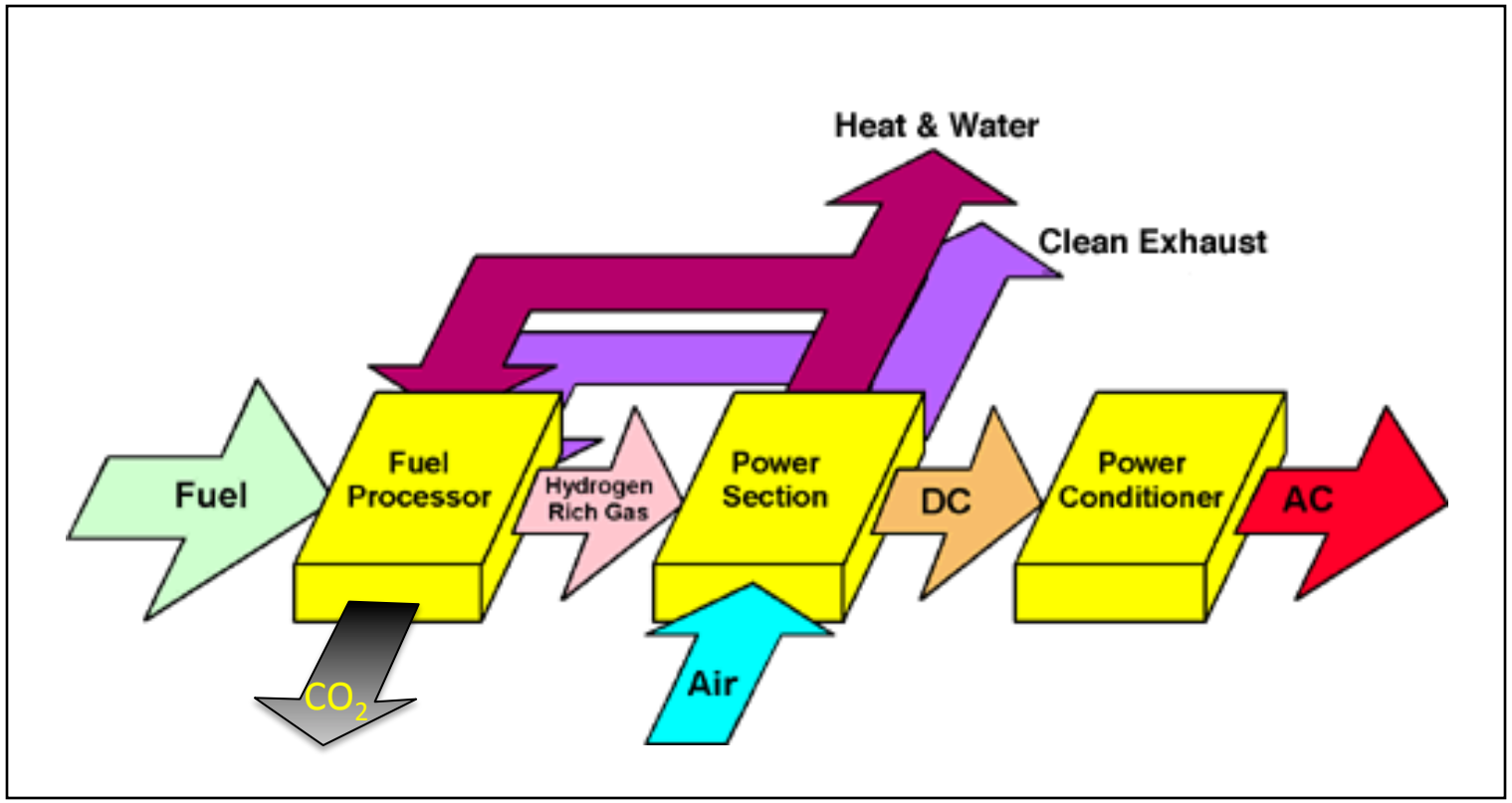
Injected storage current





Ramp rate 10% to 90 % ~2 cycles

Fuel cell System



Ramp rate: slow (basically a constant source)

Summary of DER issues

lb/kWh	N0x	CO2	Efficiency	Ramp rate: Time 10% to 90%
Diesel Engine (2 MW)	0.017	1.7	45%	~1-5 mins
Combined Cycle (100WM)	0.0023	0.6	60%	~15 mins
Microturbine (100kW)	0.0005	1.19 (0.45)	28% (~80%)	~12 sec.
NG Turbine(1MW)	.0012	1.15 (0.50)	30% (~80%)	~12 mins.
Fuel Cell	~0.0	0.95 (0.45)	40% (~80%)	???
NG Advanced Engine (100kW)	.006	0.97 (0.45)	35% (~80%)	~0.06 sec
Storage	--	--	85%-95%	~0.06 sec

(…) Indicates use of waste heat

"Air Pollution Emission Impacts Associated with Economic Market Potential of DG in California," June 2000

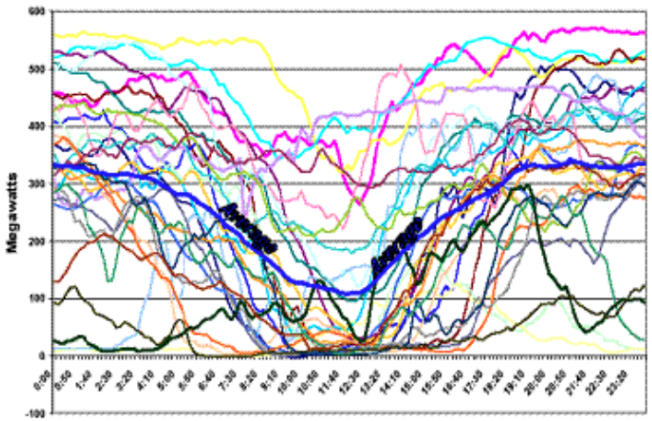
Intermittent sources:(Wind and Sun)

Wind Speed and Sun vs. predictable power

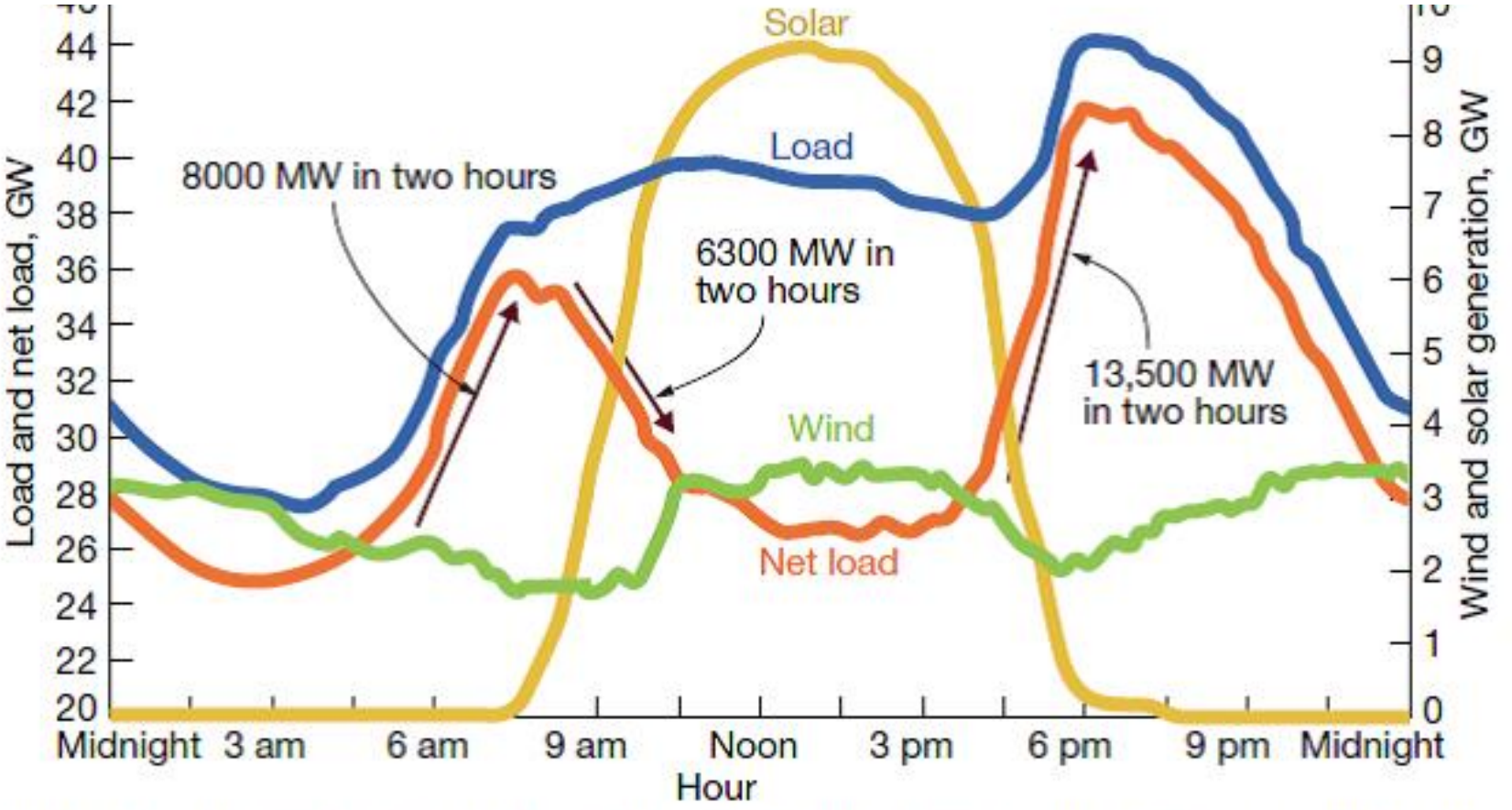
You simply cannot control weather- no wind/sun-, no power. Since wind/sun levels directly affects power output, you end up with *Intermittent power sources*

Reserve/Back-up generation

This requires that there must be standby generation to provide the power imbalance do to these intermittent sources.



DER Renewable Issues

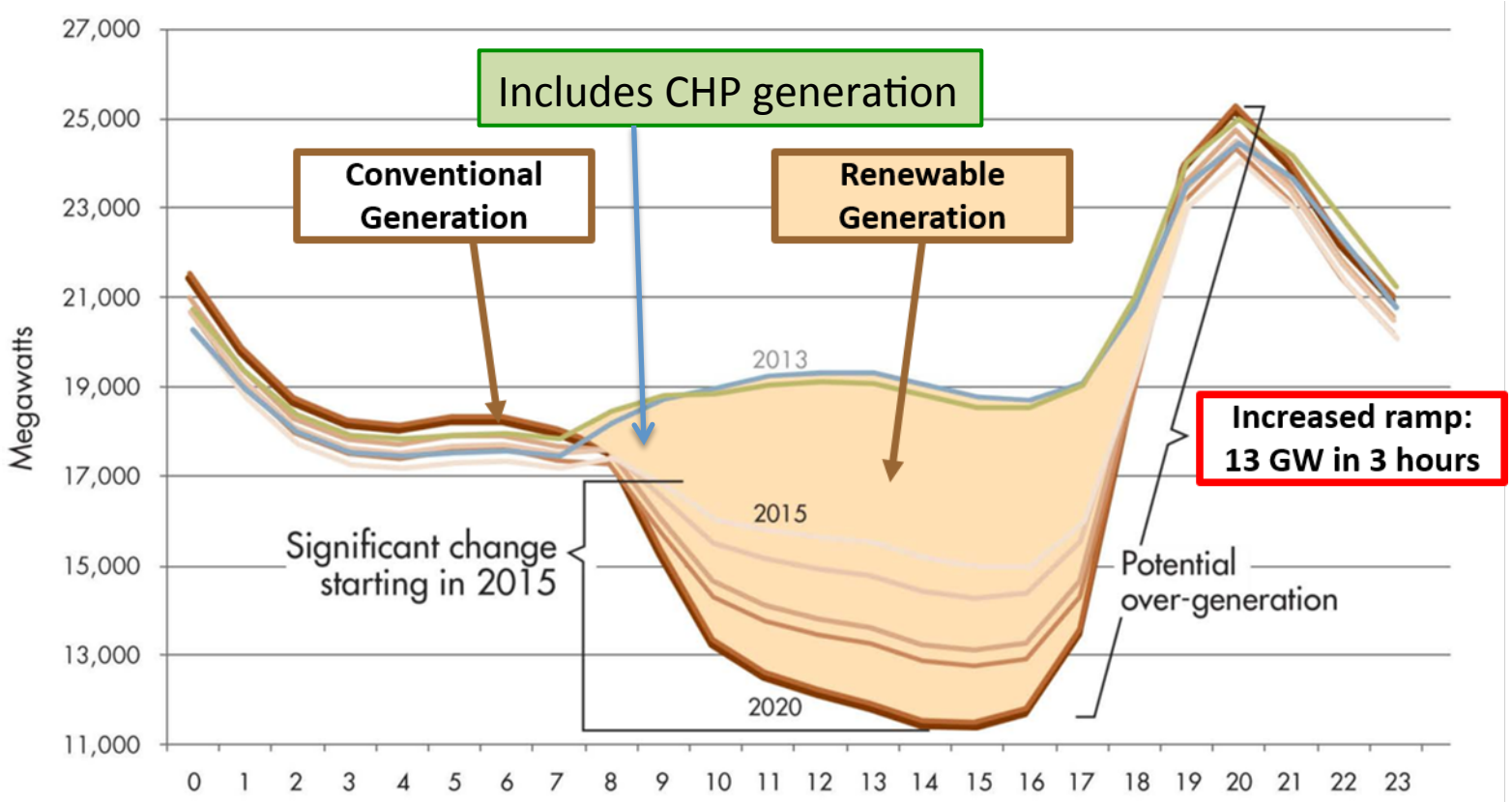


The ramping up and down is loss revenue and stressful to the equipment.

California ISO Projection for January 2020

The "Duck Graph"

Potential for over(excessive) generation



Simple Payback (years) for key 100kW DER

100kW	Wind	PV*	NG CHP**	Micro-turbine	Fuel Cell	Storage
Cost $/kw	$5,000	$5,000	$1,300	$2,600	~$9,000	?
Simple Payback (Years)	45	14-21 (8-12)W	2-4	~4-8	>45	?

*P V with incentives, NREL

**NG $4.00- $6.00/MMBtu, 100% utilization of waste heat, Oak Ridge National Laboratory,

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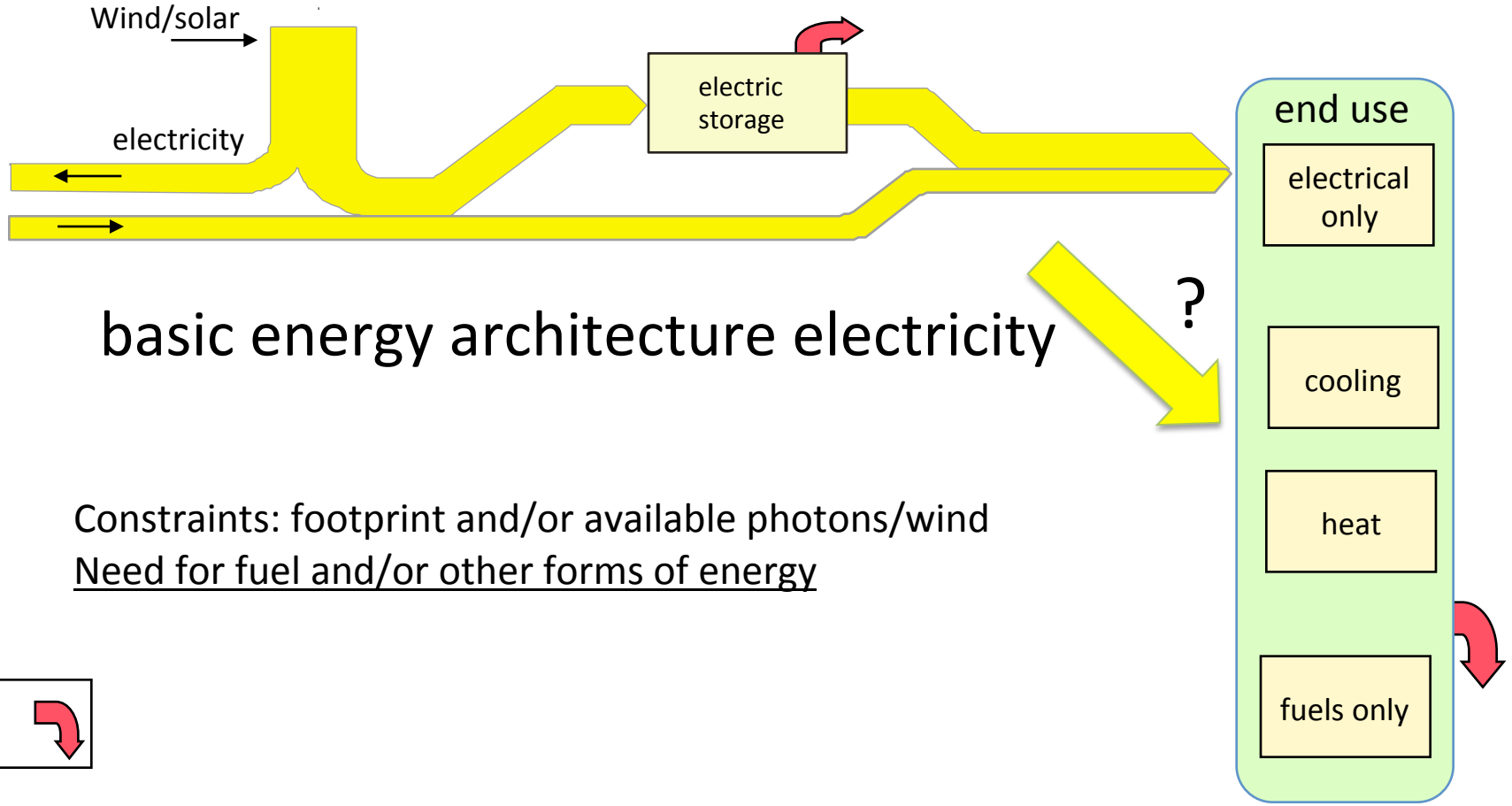
Potential of Distributed Energy Resources

- ✓ Create more reliable/efficient systems using DER near loads
- ✓ Commercial DER is approaching parity with central generation
- ✓ Wind and solar are becoming a problem for the utilities

Energy Systems Integration using DER (home to campus)

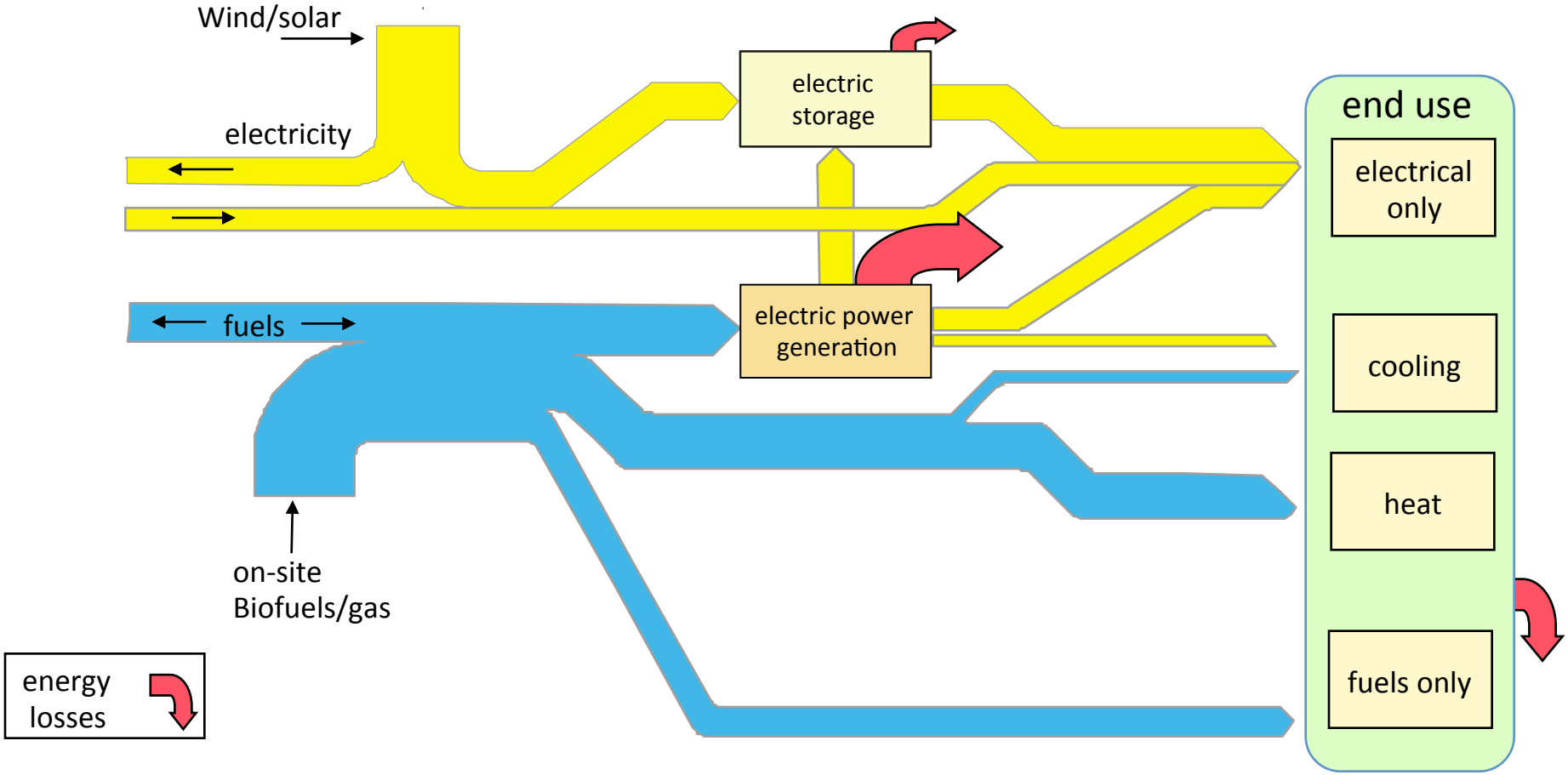


basic energy architecture electricity

Constraints: footprint and/or available photons/wind

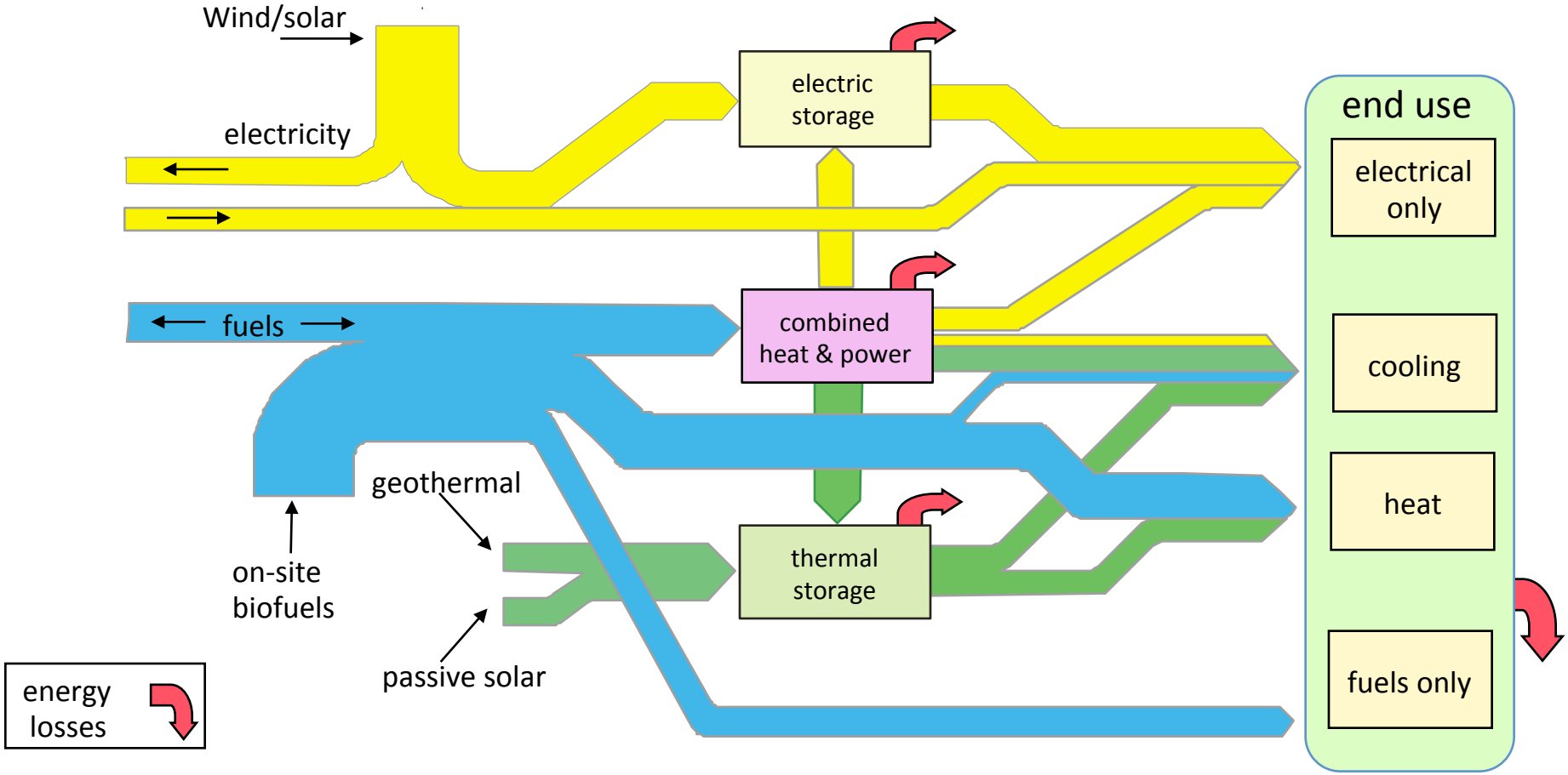
Need for fuel and/or other forms of energy

electricity and fuel architecture

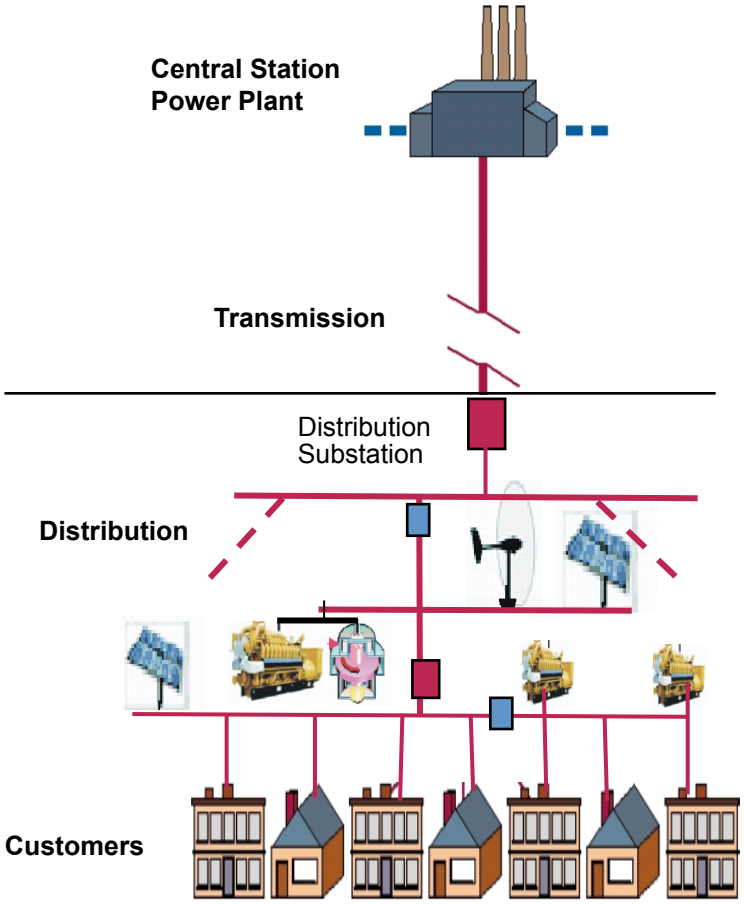


thermal management is key

Basic energy architecture

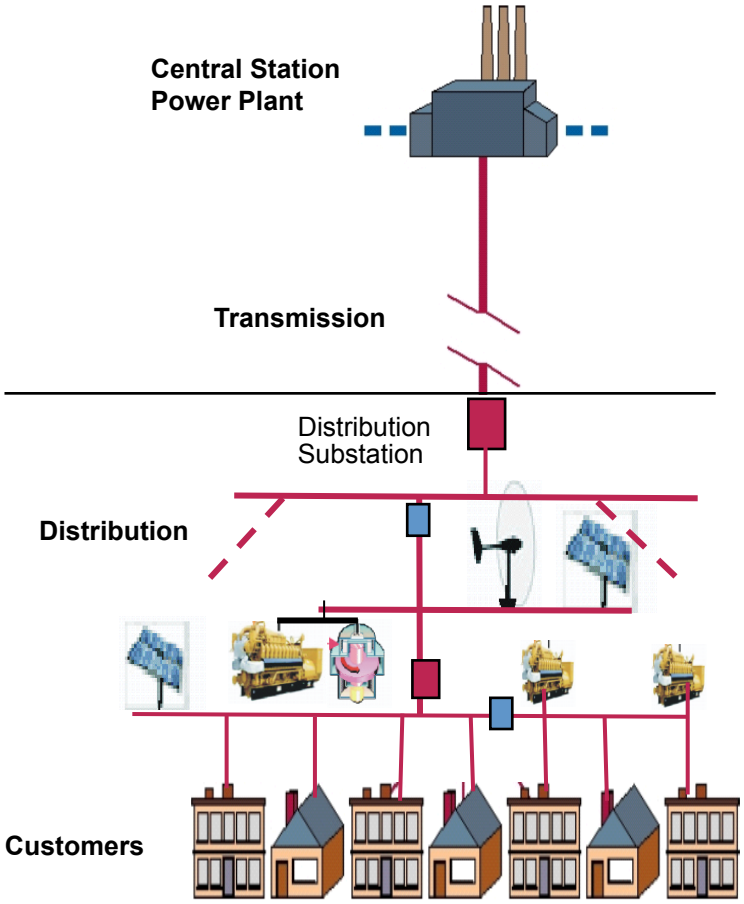


100s of thousands of energy resources



The issue is figuring out how to manage this wide, dynamic set of distributed energy resources and their control points.

100s of thousands of energy resources



The issue is figuring out how to manage this wide, dynamic set of distributed energy resources and their control points.

Move DER control and marketplace to the distribution system