# Advanced Cooling

**Andy Howell**

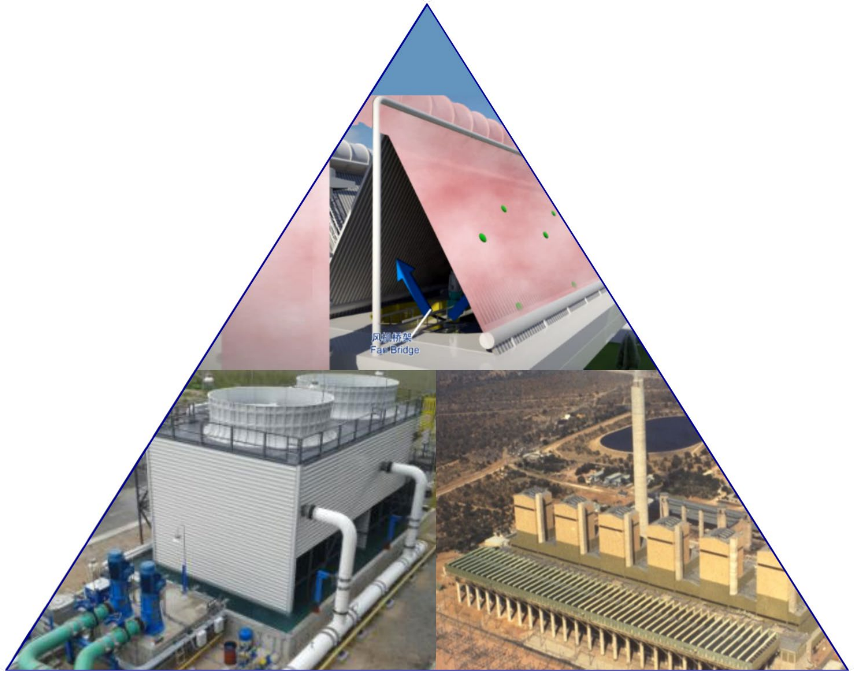
ACCUG Colorado Springs

October 8-11, 2018

# Objective

To identify and evaluate advanced cooling technologies and provide resources for optimizing cooling systems through improved efficiency and reduced water use

**Improved Efficiency**



**Lower Cost** **Less Water**

# Existing U.S. Power Plant Cooling Technologies

Based on MW generation (includes nuclear)

| | |
|---|---|
| ▪ Evaporative cooling tower | 61% |
| ▪ Sensible cooling (once-through) | 37% |
| ▪ Dry cooling (direct ACC) | 1.5% |
| ▪ Hybrid cooling (ACC + wet cooling tower) | <0.2% |
| ▪ Other | <0.5% |

*Source: U.S. Energy Information Administration, 2016*

# Why is there a need for "Advanced Cooling"?

- Evaporative cooling tower
  - environmental discharge regulations
  - withdrawal regulations
  - water quality
  - water supply
  - often unavailable for new plants

# Why is there a need for "Advanced Cooling"?

- Sensible cooling (once-through)
  - environmental discharge regulations
  - withdrawal regulations
  - ongoing accessibility
  - unavailable for new plants

# Why is there a need for “Advanced Cooling”?

- Dry cooling (direct ACC)
  - reduced performance vs. wet cooling (increased $CO_2$ emissions)
  - loss of up to 20% steam turbine generating capacity during hot ambient weather

# Why is there a need for "Advanced Cooling"?

- Hybrid cooling (ACC + wet cooling tower)
  - some performance deficit vs. 100% wet cooling
  - water may be completely unavailable for many facilities

# Metrics: Existing vs. New Technologies

| Metric | Proposed Sources |
|---|---|
| Water withdrawal per MW | Energy Information Administration |
| Water consumption per MW | |
| Fuel consumption per MW | |
| $CO_2$ generated per MW | |

| | |
|---|---|
| Capital cost per MW | Operating companies, OEMs, EPCs |
| O&M cost per MW (energy penalties / preventive & reactive maintenance) | |

| | |
|---|---|
| Heat transfer characterization | Various (suitable and credible) |
| Net plant efficiency | |
| Other / special issues | |

# Phase 1: Short-term Goals (1 – 5 years)

- Cost-effective increase in power generation
  - Addition of wet cooling to existing dry systems
  - Incorporation of hybrid cooling into new construction
  - Technologies to enable use of alternative water sources
- Cost-effective reduction in water consumption
  - Addition of dry cooling to existing wet systems
  - Incorporation of dry cooling into new construction
- *Using existing technologies or adaptations*
- *Demonstration projects with technology transfer communications*

# Retrofits:
# Addition of wet evaporative cooling to direct dry cooling

# Retrofits:
# Addition of direct dry cooling to wet cooling





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# Phase 2: Intermediate Goals (2 – 10 years)

Steam cooling systems ready for installation with the following characteristics:

- Reduction in performance gap between direct air cooling and evaporative cooling by 50%

  *and*

- Reduction in water consumption for evaporative cooling by 50%

  *and*

  – Capital and operating costs no greater than those for existing evaporative cooling

# Phase 3: Ultimate Goals (10 - 20 years)

Steam cooling system(s) ready for installation with the following characteristics:

- Performance equal to, or better than, existing wet evaporative technology, but with no significant routine consumption of water

  *and*

- Capital and operating costs no greater than those for existing wet evaporative cooling

# Phase 3: No water loss? As effective as Evaporative cooling?

## Example 1: Thermosyphon cooling

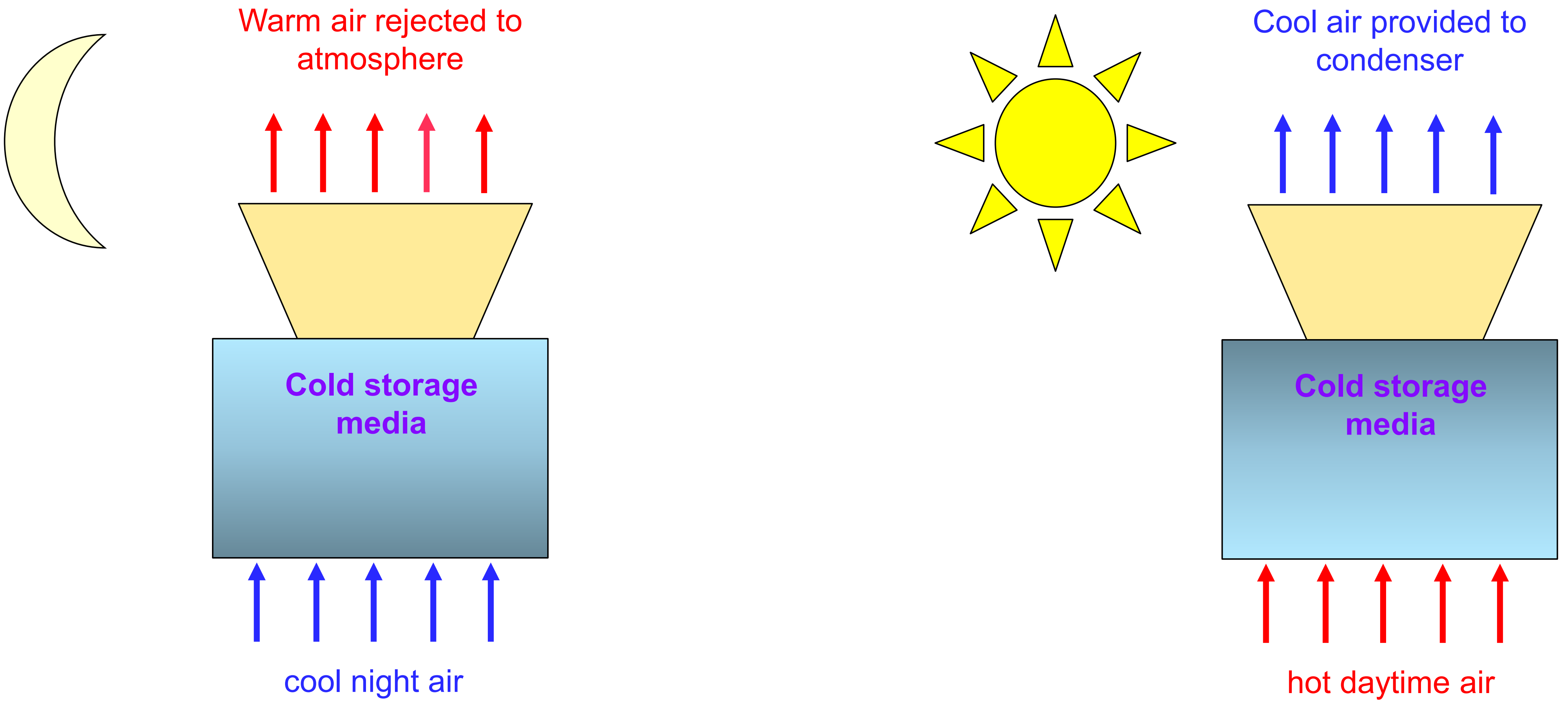
Concept: Refrigerant is used to cool water via heat exchanger as it vaporizes, then is circulated through an air-cooled section where it condenses and returns via gravity / siphoning action to provide water cooling.

# *BlueStream*™ Thermosyphon Cooler

# Phase 3: No water loss? As effective as Evaporative cooling?

## Example 2: Cold storage

Concept: media suitable for thermal absorption and retention is cooled with night air, and is subsequently available for cooling warm daytime air.


Warm air rejected to atmosphere
Cold storage media
cool night air
Cool air provided to condenser
Cold storage media
hot daytime air

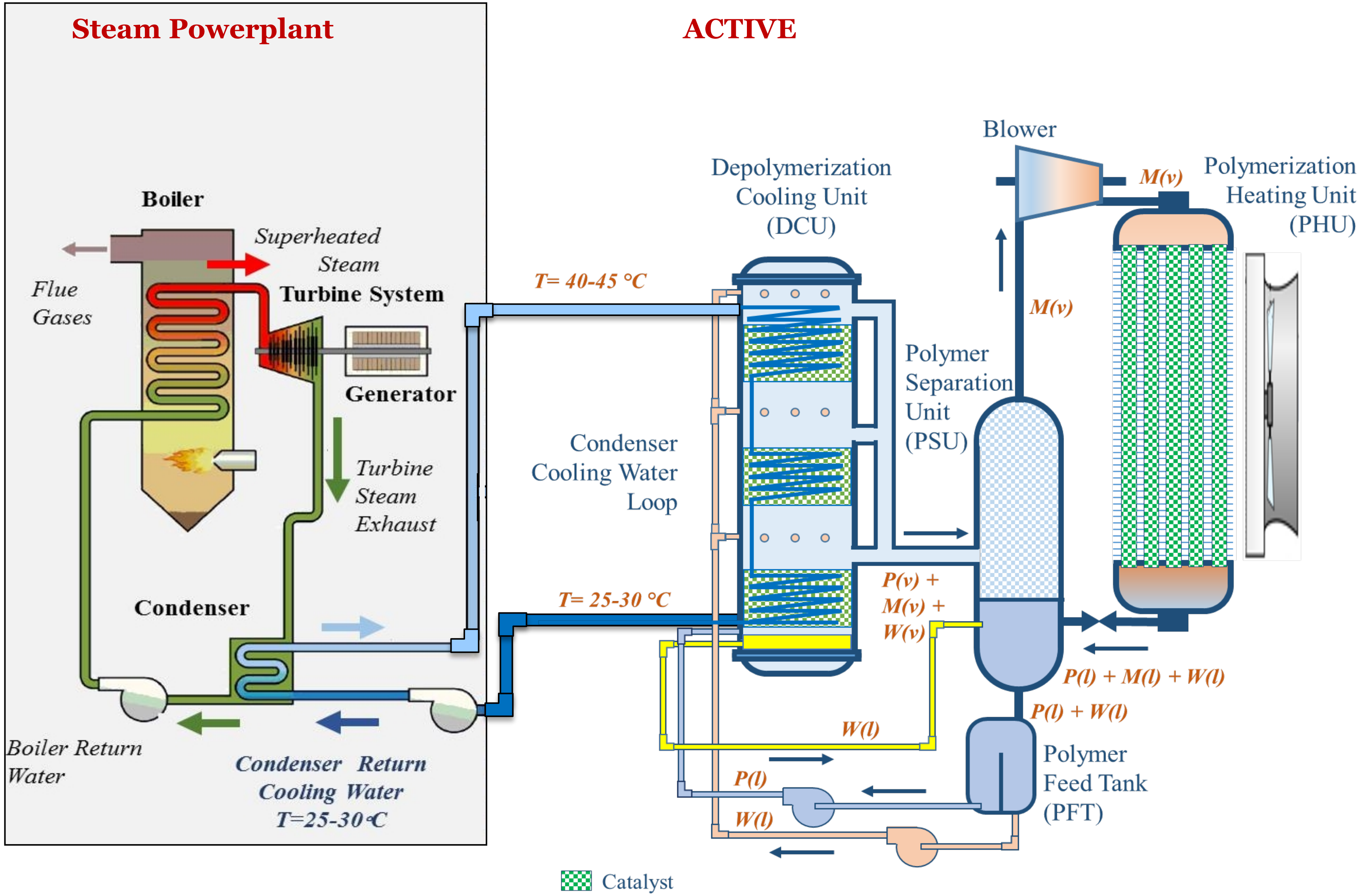
# Phase 3: No water loss? As effective as Evaporative cooling?

## Example 3: Polymerization / depolymerization

Concept:

- Acetaldehyde **absorbs** heat during catalytic polymerization to form polymer paraldehyde (cools recirculating water)
- Paraldehyde **rejects** heat to atmosphere during catalytic depolymerization to form monomer acetaldehyde

# ACTIVE System Process Diagram




## ACTIVE Chemical Heatpump

Depolymerization and Evaporation
Endothermic Process
**DCU**

$$P_{(l)} \leftrightarrow 3M_{(l)} \leftrightarrow 3M_{(g)}$$

**PHU**

Polymerization and Condensation
Endothermic Process

$$\Delta H = 189.5 \frac{kJ}{mol_P} = 1{,}434 \frac{kJ}{kg_P}$$

# No water loss. As effective as Evaporative cooling.

Additional concepts / research will be under ongoing investigation for achieving these ultimate goals.

# Next Steps

- Seeking input on objectives, approach, metrics, goals, research needs, and timelines
- Requesting ideas for potential technology applications
  - Current operations and/or maintenance challenges
  - Potential future challenges and industry trends
- Planning technical and programmatic review

# Save-the-Date

- IAHR Industrial Cooling Towers Conference 2019
  October 7-12, 2019 | Washington, DC

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