Effects of Climate Change on the Midwest Electricity Sector

PCCRC Lit Club

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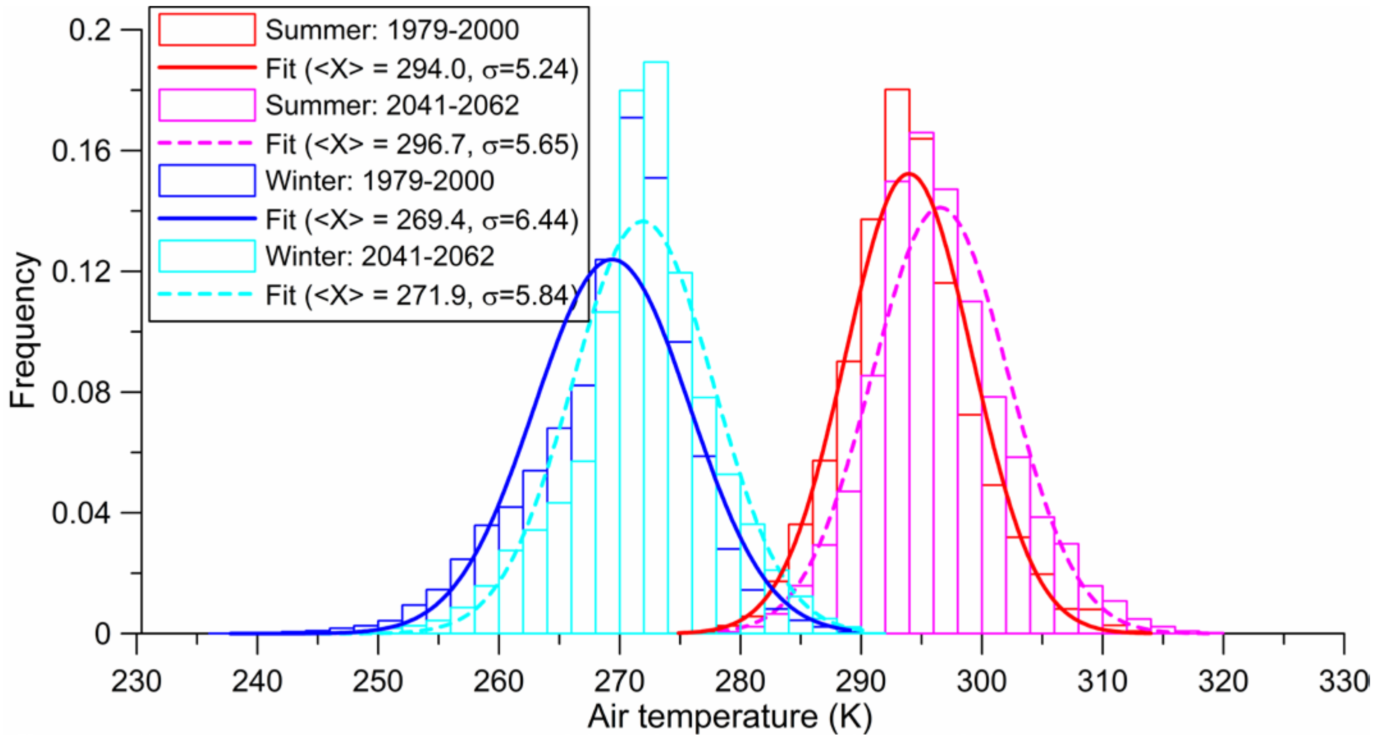
Susceptibility

	Temperature	Precipitation	Storms
Demand	●		
Supply	●	●	●
Delivery	●		●

Demand vs. Temperature

- There are two primary areas where demand is sensitive to temperature.
- Winter space heating
  – Warmer temps mean lower heating load.
- Summer space cooling
  – Warmer temps mean higher cooling load.
  – Increased humidity also increases cooling load.
  – Longer duration heat waves also increase cooling load.

Distribution of Temperatures - Indianapolis



From simulations conducted with the Canadian Regional Climate Model

The Midwest is Summer Peaking

- We use other fuels (natural gas, propane) more than electricity for space heating.
- Nearly all air conditioning uses electricity.
- As a region, the highest level of demand (the peak) occurs on a hot, humid summer weekday.
- Peak demand is important because it drives generating resources needs (and hence, costs).

Effects on Demand

- To the extent that average temperature increases, we would expect somewhat lower electricity usage in the winter and higher usage in the summer.
- Increased humidity and longer heat waves would increase summer demand further.
- Costs of supplying the demand would be higher.

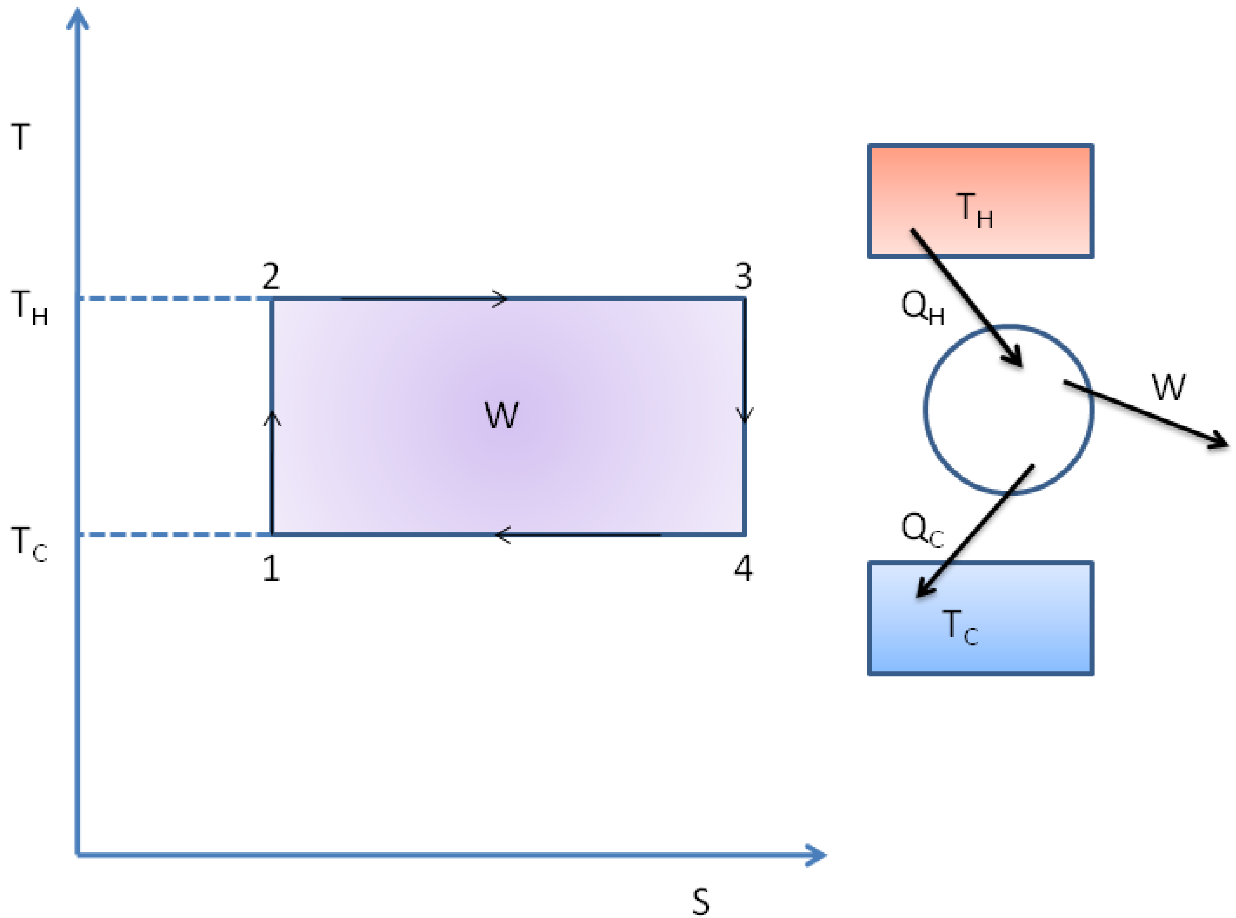
Temperature vs. Supply

- Most of our generators are affected (in terms of efficiency and maximum output) by ambient temperature.
- 95% of electrical energy in the Midwest (in 2009) comes from either steam plants or combustion turbines.
- As temp ↑, air density ↓, which reduces the efficiency of combustion turbines.
  - Summer capacity rating can be as much as 20% lower than the winter rating.

Steam Cycle

- In a steam cycle, a heat source (usually through fuel combustion or nuclear fission) adds energy to boil water. The steam is used to turn a turbine attached to a generator. The exhausted steam is condensed back to liquid and returned to the boiler.
- The maximum achievable efficiency, aka the Carnot efficiency (η) is determined by the temperature of the heat source (T_H) and the temperature of the heat sink (T_C).

The Carnot Cycle



Carnot Efficiency

- $\eta = 1 - \frac{T_C}{T_H}$ where temperature is measured on an absolute scale.
- The steam temperature (T_H) is a design feature of the plant and does not change with ambient temperature.
- The condensate temperature (T_C) is affected by the ambient air temperature (if a cooling tower is used) or by the temperature of the cooling water source (river, lake, or reservoir).
- As air or water temperature ↑, efficiency ↓.

Precipitation vs. Supply

- Hydroelectricity is obviously affected, but the Midwest uses little hydro (less than 2% of our electricity).
- Most of our hydro is run-of-river, which means that the water cannot be stored.
  - Excessive water is spilled rather than saved for later.
- Thus, increased flooding and droughts could reduce output even if average precipitation does not change.

Storms vs. Supply

- Most of our generation sources are not particularly vulnerable to storm events.
- Wind and solar are the exceptions due to their exposure to the elements (wind, lightning, ice).
  - These are currently a small but growing portion of our generation portfolio.
- Thus, changes in the frequency, location, and severity of storm events will only have a small impact on electricity supply.

Temperature vs. Delivery

- The power lines used to transmit electricity through the network generally consist of aluminum strands with steel reinforcing cables.
- As current flows through the lines, heat is produced which is dissipated through the air.
- High air temperatures with little wind can reduce the dissipation and limit the capability to transmit power without damaging the cable.

Line Sag

- As the conductor temperature ↑, the aluminum expands.
- Since the distance between the towers is fixed and the line is now longer, it sags.
- If the sagging line contacts or comes too close to buildings or vegetation, a fault occurs which takes the line out of service.
- Thus, high ambient temperature can have an adverse effect on reliability.

Storms vs. Delivery

- Storms are the primary threat to reliability.
- Lightning, high winds, and tornadoes are all significant in the Midwest.
- Winter storms can be problematic here (as opposed to hurricanes in other regions) since restoration can be difficult due to limited access to damaged facilities and the widespread nature of the damage.
- Changes in the frequency, location, and severity of storm events could have a large impact on electricity delivery.

Further Information

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