Class Notes:

Finding Other Types of Generation to Replace Norris Dam Hydropower Plant

1. Norris Dam Hydropower Plant

$$P_{Water} = E_{Potential} / t = V \rho g h / t = q \rho g h$$
$$P_{Out} = \eta P_{Water} = \eta q \rho g h = 9.81 q h \eta \quad (kW)$$

Norris Dam (132MW) on Clinch River: 570m Long x 81m High, constructed in 1936 by \$36M Assume Clinch River's discharge is 1/10 of Tennessee River ($2000m^3/s$): Discharge q = 200 m³/s Pout=9.81 x 200 x 81 x 80% ≈128000kW=128MW

Total energy/year = $128000 \times 365 \times 24 = 1.1 \times 10^9 \text{ kWh/year}$

 <u>How many homes to be powered?</u> Average TN household consumes 8,000kWh/year 1.1x10⁹ /8,000=140K homes (homes: 80K in Knoxville, 160K in Knox County)

2. <u>Thermal power plants:</u>

If it is replaced by a coal-fired or natural gas power plant:

• <u>CO2 emission</u>

Coal:	$2.11bs/kWh \sim 0.95kg/kWh$	$1.1 \times 10^9 \times 0.95 / 1000 = 1 M \text{ tons}$
Natural gas:	1.2lbs/kWh ~ 0.54 kg/kWh	$1.1 \times 10^9 \times 0.54/1000 = 0.54 \text{ M tons}$

3. Solar PV

How much total area of PV panels needs to be installed in Knox country to replace Norris Dam? 128000kW x 24h = 3M kWh /day Tennessee solar radiation: 5 kWh/m²/day Total area = 3M/5 =600,000 m² =0.6 km² Roof solar panel: 600, 000 / 160, 000 < 4 m² / home ~ 40 ft² / home

4. Wind turbine

$$\overline{P_o = \eta C_P P_W} = \eta C_P \frac{\pi D^2 \rho v^3}{8} \quad (W)$$

Assume Po=100MW

• How large is the diameter D of a single wind turbine to have a capacity of 100MW? D=sqrt($P_o \ge 8 / (\eta \ge C_p \ge 3.14 \ge v^3 \ge 1.2)$) World largest turbine: Po=10MW, D=160m

- Where to place the world largest turbine for 100MW? (find v) D=sqrt($10x10^6 \times 8/(1 \times 0.4 \times 3.14 \times v^3 \times 1.2)$)=160m -> v=13m/s=29mph
- TVA Buffalo Mountain wind farm near Oak Ridge: 15 large wind turbines + 3 small turbines (total 29MW for 3780 homes) Each: D=80, v=25mph~11m/s, find Po

$$P_{o} = \eta C_{P} P_{W} = \eta C_{P} \frac{\pi D^{2} \rho v^{3}}{8}$$
 (W) = 1.6MW (Actual: 1.8MW)