

The Case for Renewable Energy

EES 3310/5310

Global Climate Change

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Two perspectives on worldwide decarbonization: 50% below 1990 by 2050

Pielke	Alternate
<ul style="list-style-type: none">• Cutting emissions to 10,800 MMT by 2050 would mean building<ul style="list-style-type: none">■ 4.4 nuclear power plants per week for 40 years■ Or 1000 solar plants per week■ Or 4000 wind turbines per week• This sounds impossible	<ul style="list-style-type: none">• Meeting growing energy demand with fossil fuels would mean building<ul style="list-style-type: none">■ 3 coal-fired plants per week■ Or 3 nuclear plants per week• If demand for coal grows at almost 2% per year, what happens to price?

Conclusion: Providing energy will be a big challenge whether we use clean energy or fossil fuels.

Jacobson & Delucchi:

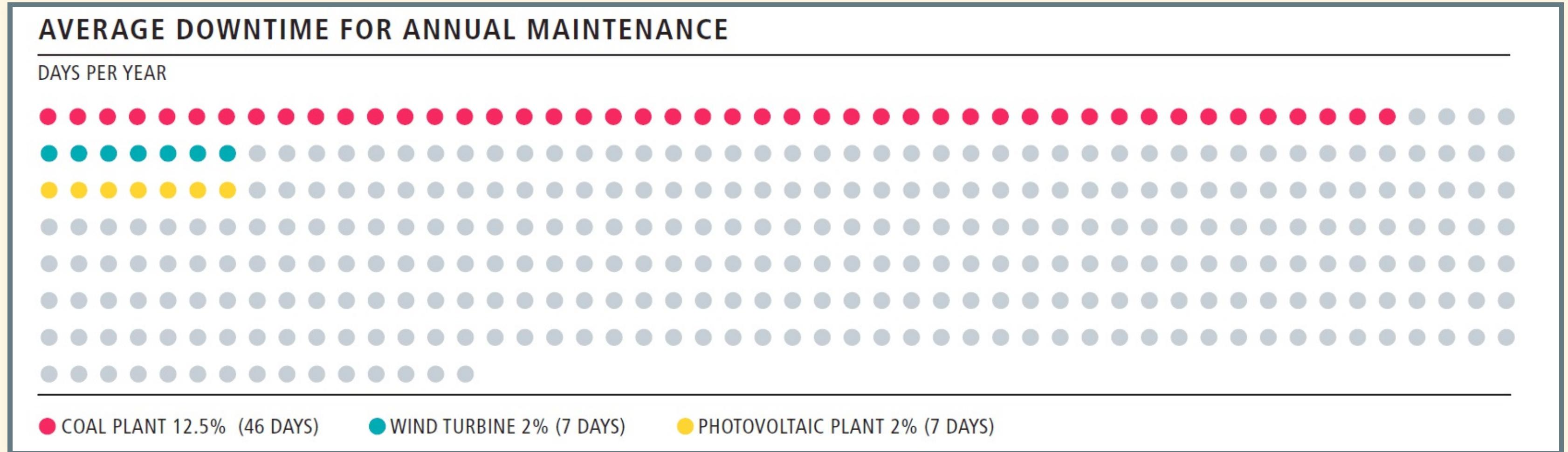
End-Use Power (Trillion Watts)

	2010	2030
US	2.5	2.8
World	12.5	16.9

Note: 1 TW = 90 quads/year

- **Goal:**
 - *All new* energy from Wind, Water, Sun by 2030
 - US: 0.3 TW
 - World: 4.5 TW
 - *All energy* from WWS by 2050
 - Cost: \$100 trillion over 40 years
(vs. \$10 trillion for fossil)

Efficiency from Reliability



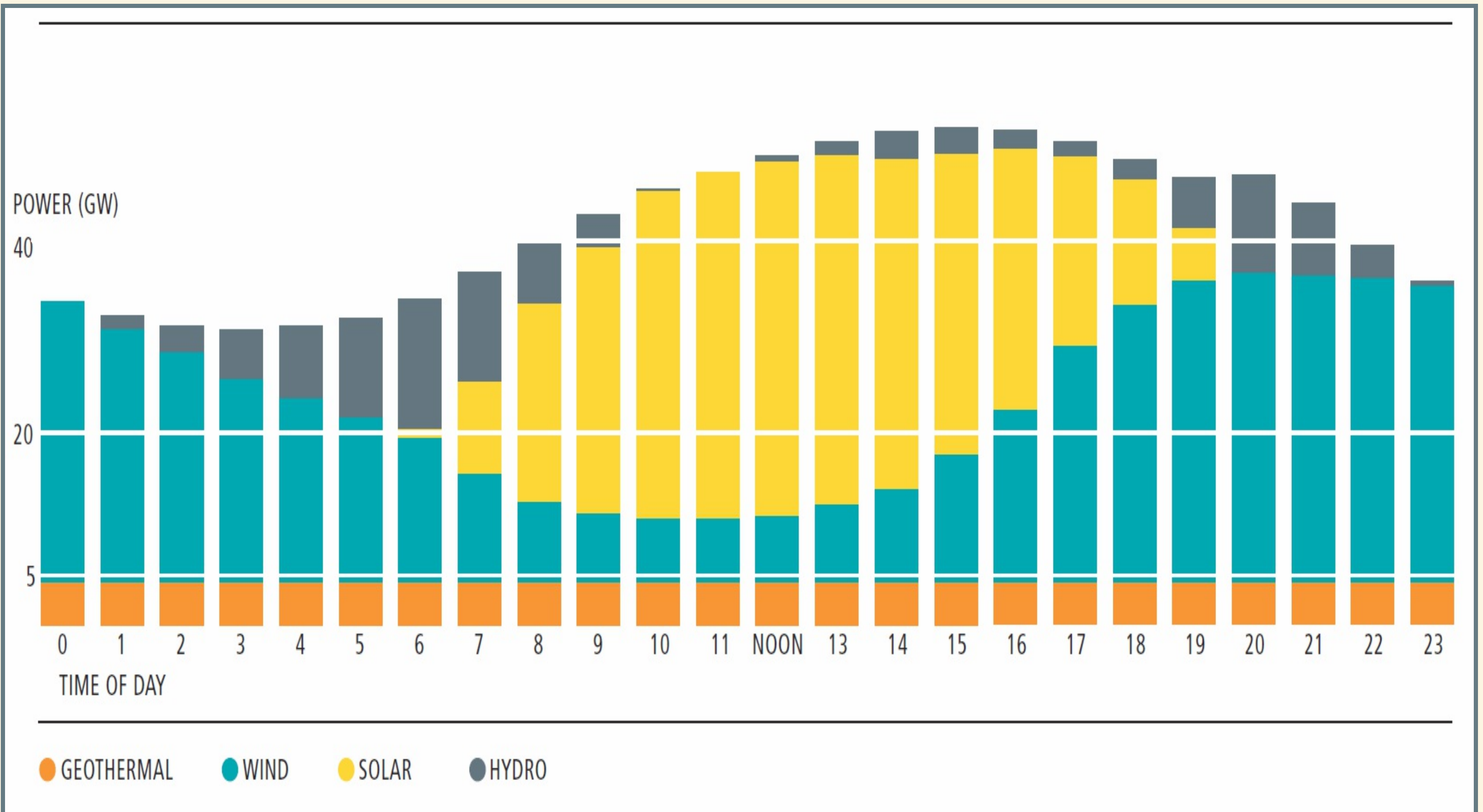
Energy Requirements in 2030:

- 16.9 TW conventional energy
- 11.5 TW with efficiency/reliability gains
- Gasoline car is 17–20% efficient
- Electric car is 75–86% efficient

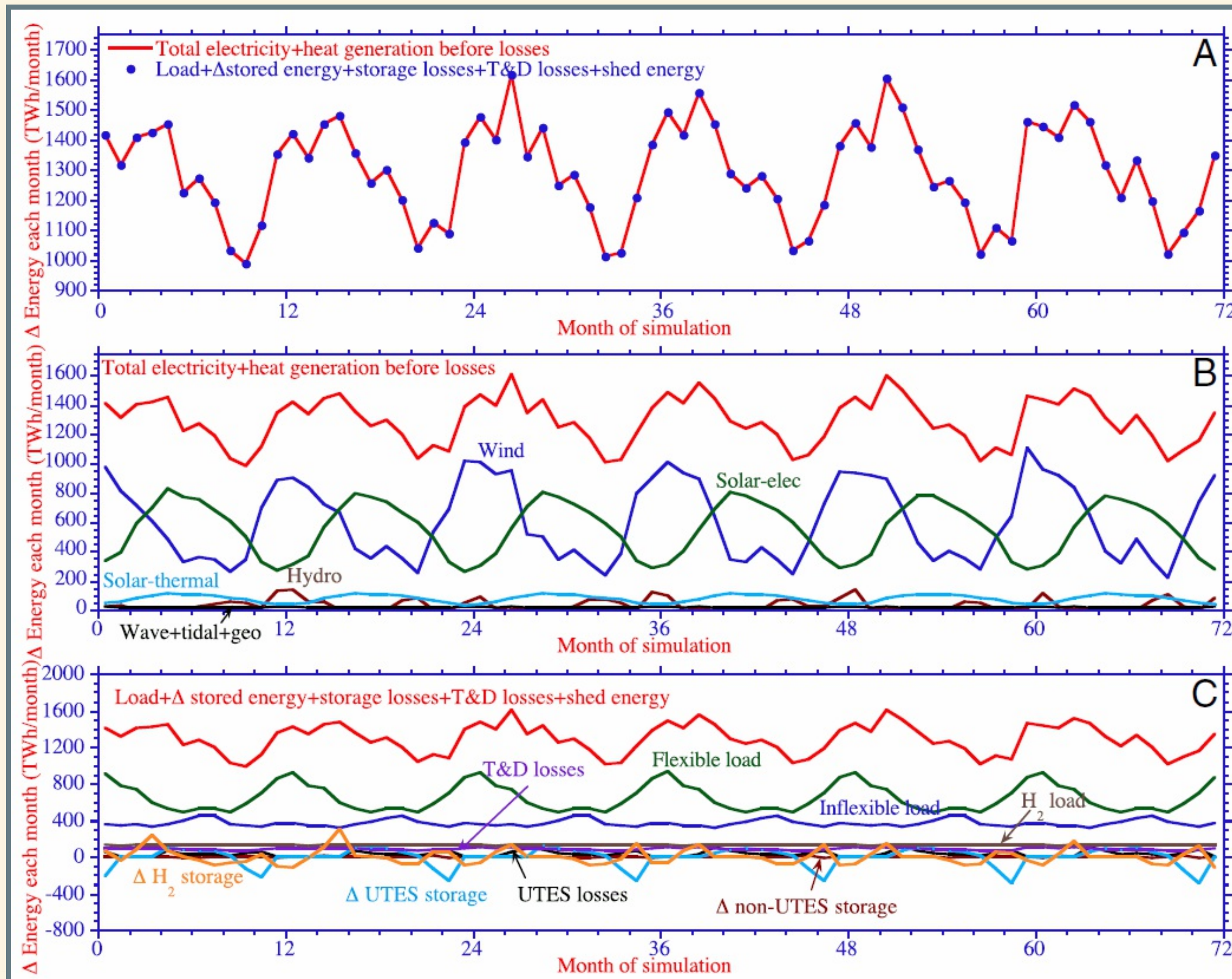
Energy Sources

Recommended	Not recommended
<ul style="list-style-type: none">• Generation<ol style="list-style-type: none">1. Wind2. Concentrated Solar3. Geothermal4. Tidal5. Photovoltaic6. Wave7. Hydroelectric• Storage<ol style="list-style-type: none">1. WWS with battery-electric2. WWS with hydrogen fuel cell	<ul style="list-style-type: none">• Coal with carbon-capture and storage• Nuclear• Biofuels

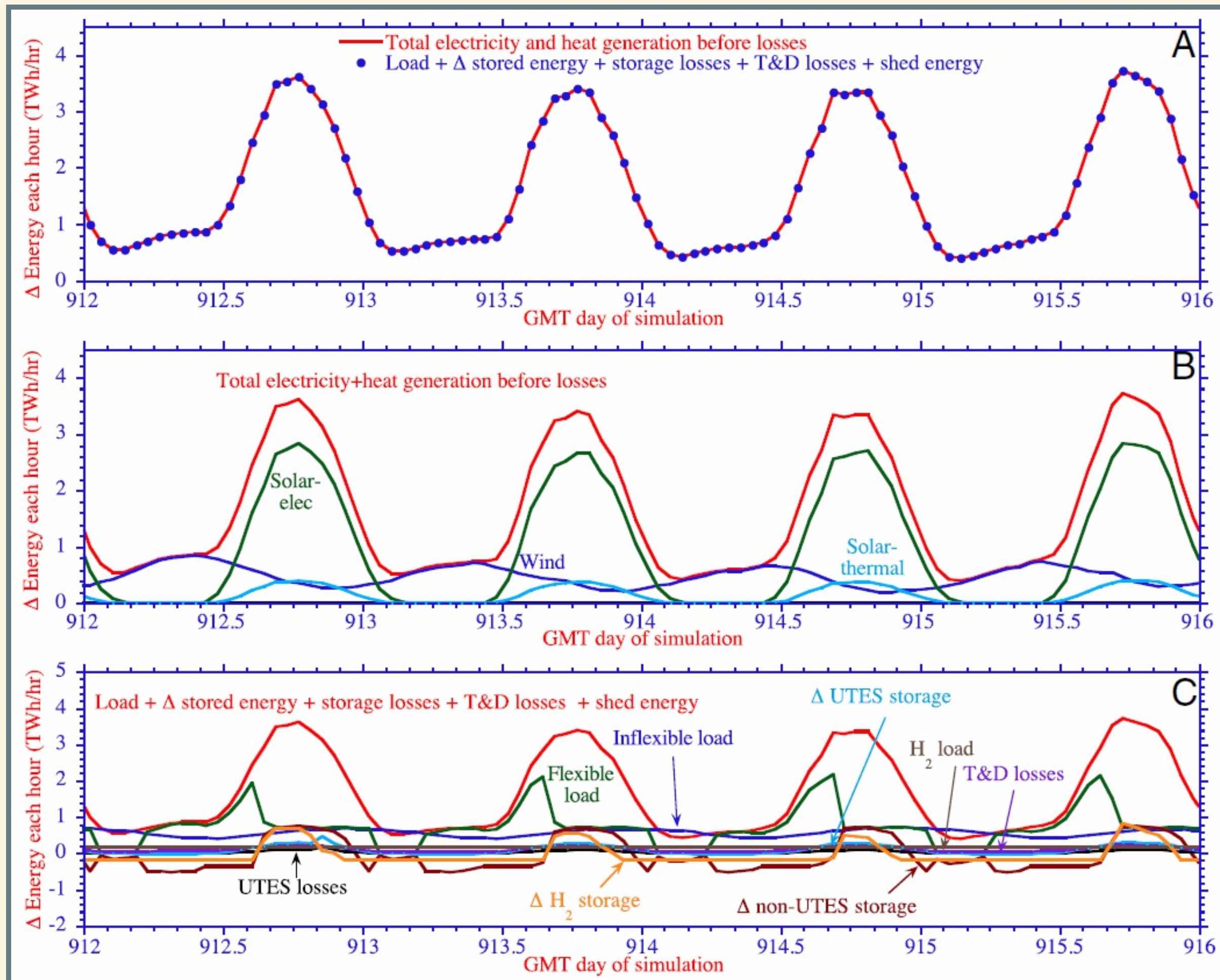
Balancing variable sources



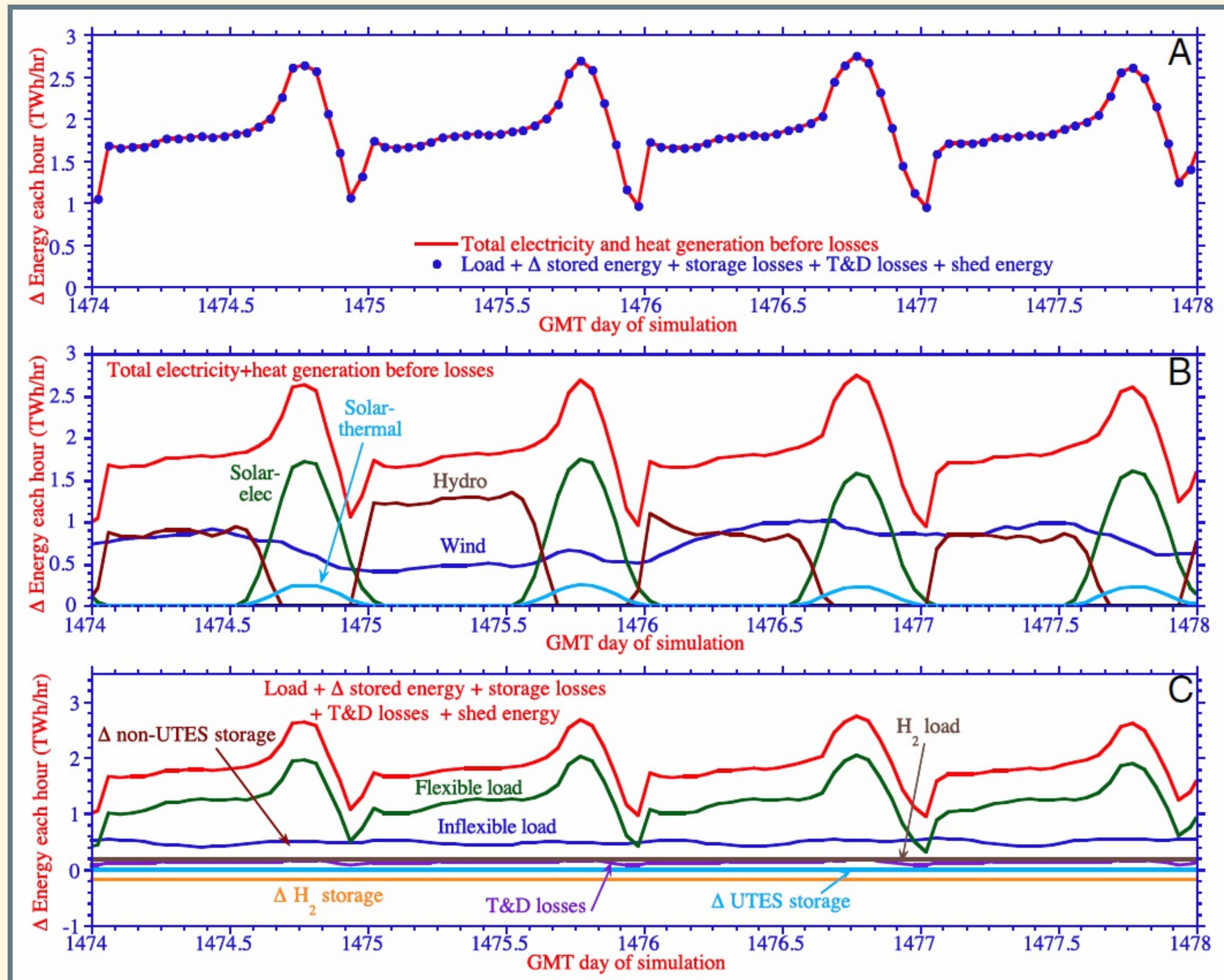
Seasonal Variations



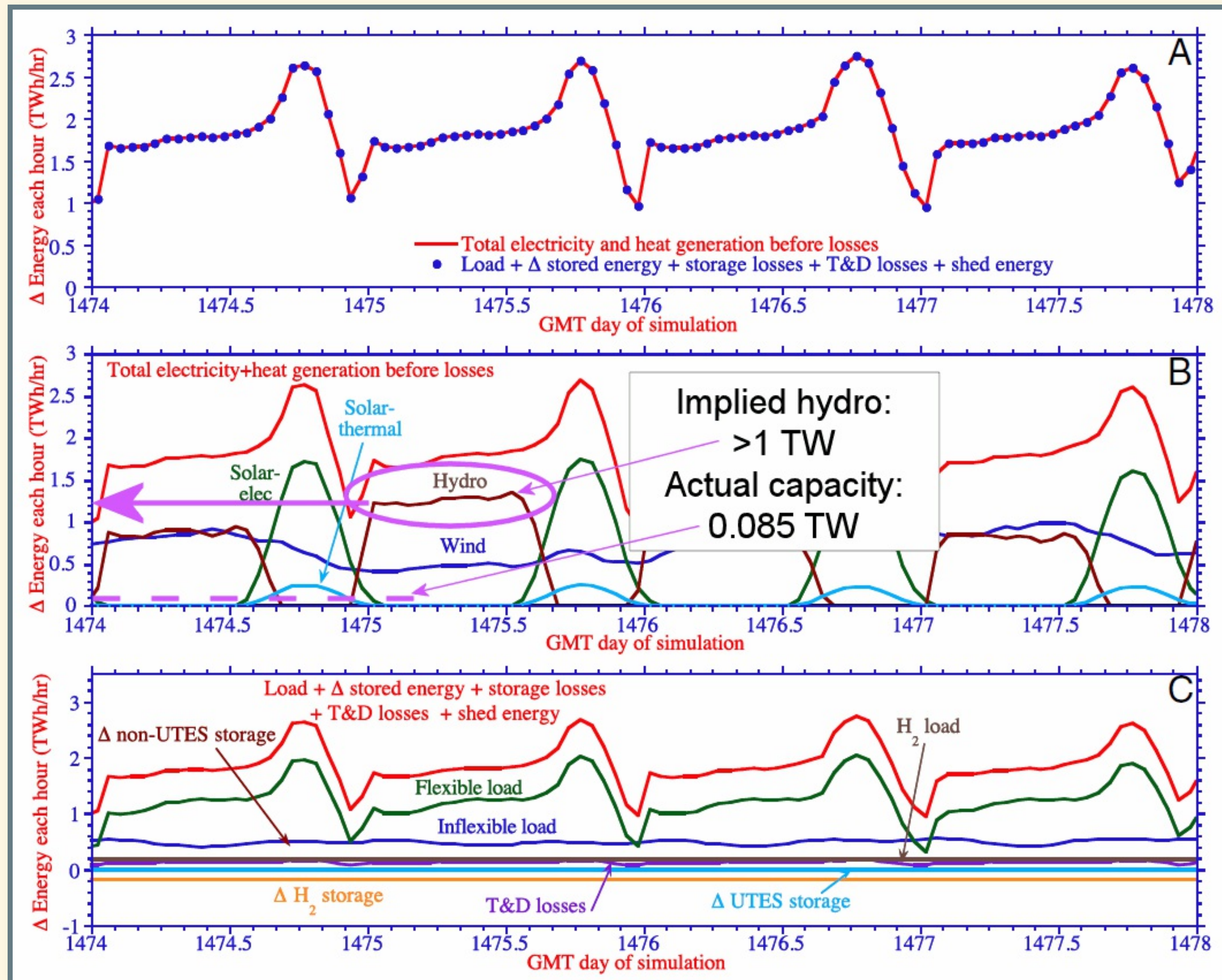
Daily Variations (July)



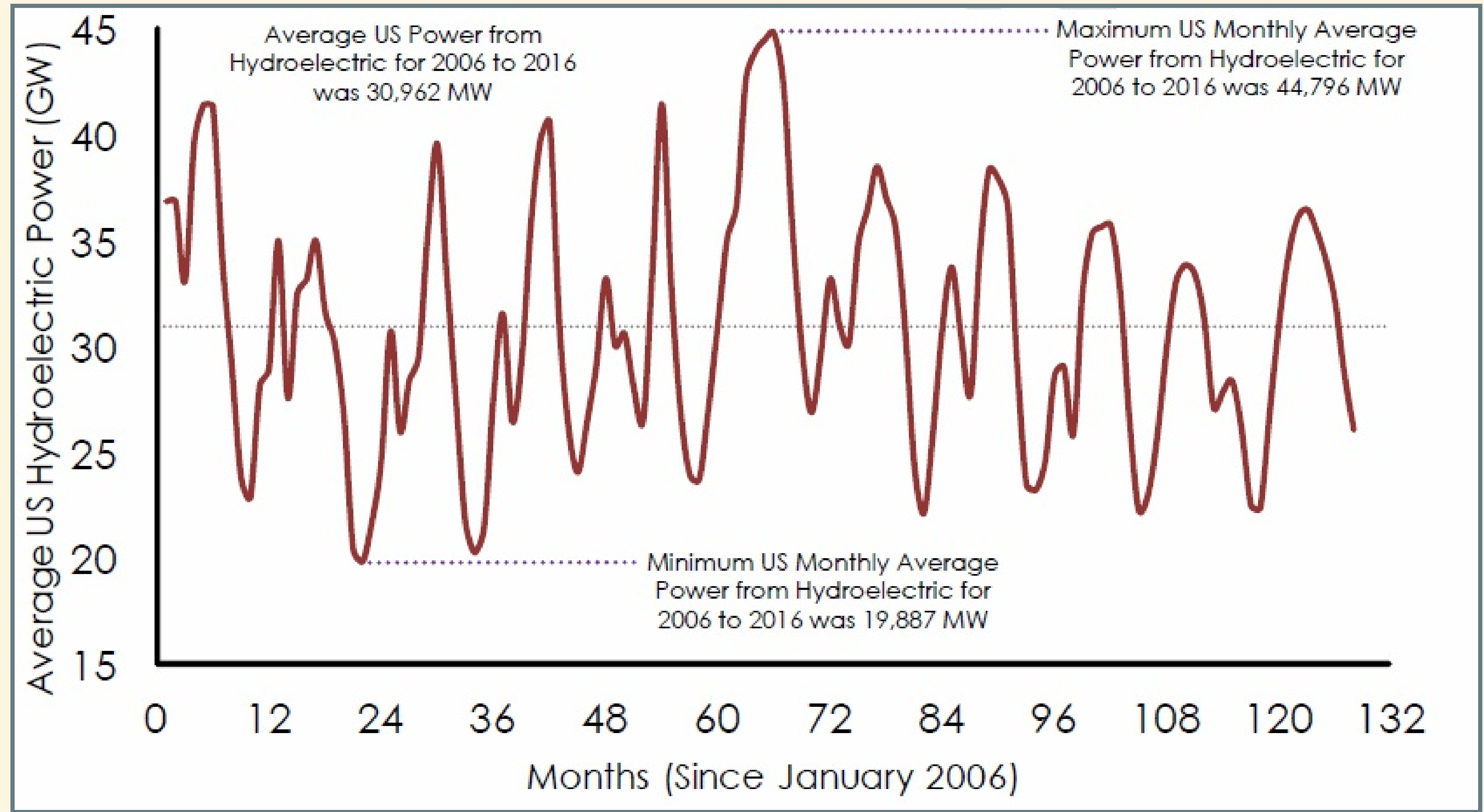
Daily Variations (January)



Plausibility of Hydroelectric Assumptions



Actual Hydroelectric Output (2006–2016)



Hydroelectricity

- Jacobson claims 1,300 GW peak hydroelectricity
- Today's capacity is ~88 GW
- Jacobson assumes 1500% increase in generating capacity for existing dams:
 - Install 15 times more turbines in existing dams
 - Peak water discharge from many dams $>5 \times$ greatest historical floods:
 - Flooding
 - Disruption of ecosystems (fish, etc.)
 - Disruption of agricultural/irrigation use
- New turbines, retrofitting dams not included in cost estimates

Energy Storage: Underground Thermal

- Assumes massive increase in underground thermal energy storage (UTES)
- Massive infrastructure (pipes, pumping)
- Possible, but very expensive, not included in cost estimates
 - Could add \$1.8 trillion

Hydrogen

- Jacobson assumes 100,000 times more hydrogen production than today's world capacity.
- Assumes hydrogen-powered airplanes by 2035

Modeling Climate and Energy

- Jacobson's analysis rests on models written by Jacobson's team
 - Many other climate models are open source, available to other scientists
 - Jacobson's are closed source
 - Other models participate in Coupled Model Intercomparison Project to compare accuracy, identify strengths & weaknesses
 - Jacobson's models have not participated
- Novel electrical supply/demand matching model LOADMATCH has not been made public or tested independently.

Big picture

- Big disagreement about small differences.
 - Jacobson's critics believe 74–84% of electricity from clean energy sources:
 - 58–68% from renewables
 - 16% from nuclear
 - 16–26% from natural gas
 - Jacobson insists 100% wind, water, solar, and believes nuclear is a very bad idea
- Even if Jacobson is correct, his cost estimate is \$100 trillion over 20–40 years (\$2.5–5 trillion per year: 3.2–6.5% of global GDP).
 - Is there political will to spend this much?
 - Jacobson claims renewable energy will repay investment in fuel savings

Latest Developments

Jacobson Sues Critics, Journal

- **Sept 2017:** Jacobson filed a \$10 million defamation lawsuit against his critics and the journal Proceedings of the National Academy of Sciences for publishing their criticisms of his work.
 - Claimed critics and journal “knowingly and intentionally published false statements of fact.”
 - Insisted his critics were corrupt and were in the pay of the fossil fuel and nuclear power industries.
- **Feb 2018:** Jacobson dropped the lawsuit