Duck curves & flywheels:
Solving the energy crisis with mechanical energy storage

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The Challenge

As non-renewable energy sources like fossil fuels become scarcer, the US is turning to renewable energy sources as a solution, leading to a current growth rate of 25% for solar energy[1]. Unfortunately, we currently lack the infrastructure to handle this energy input, resulting in an issue known as the Duck Curve.

The Duck Curve

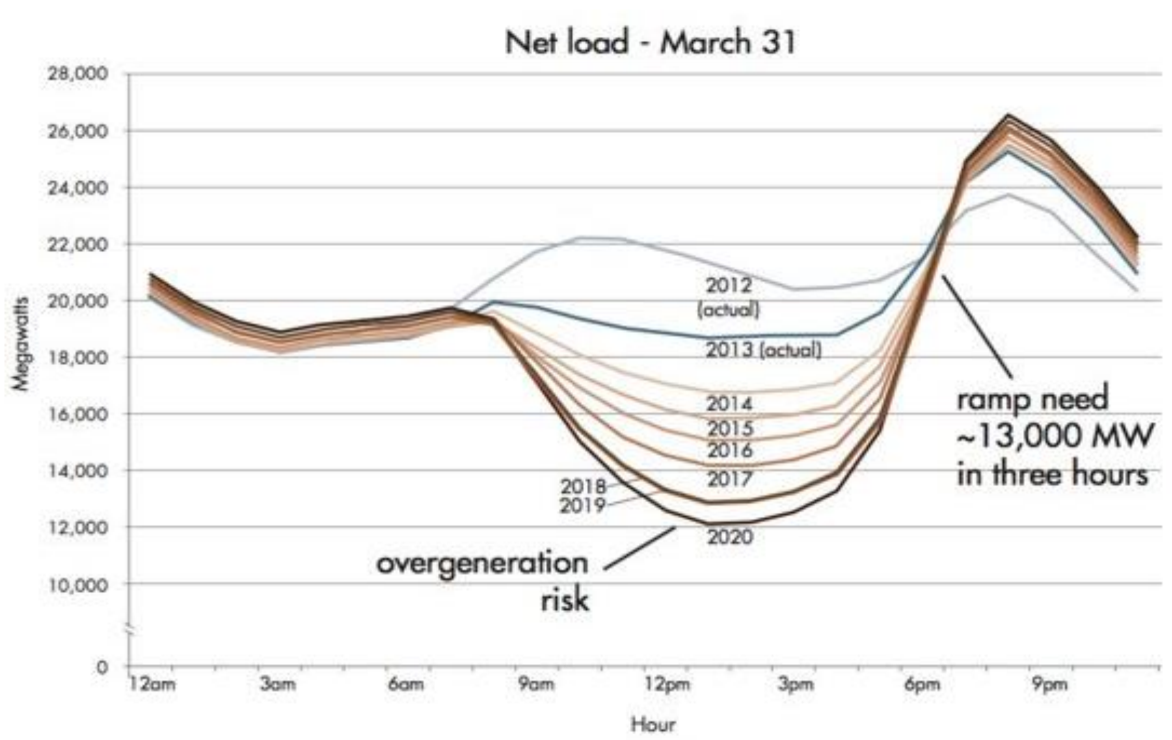

Figure 1. Duck Curve. Statistical projection of renewable energy usage in California[1]

The Duck Curve (Fig. 1) represents the main barrier preventing more efficient utilization of solar power. During the day, more solar power is produced than consumed (overgeneration), creating a dip in the middle of the graph. At night, solar power decreases, creating a need for non-renewable sources to fill the gap. To address this issue, one solution is to store and release solar power during the night to smooth out the Duck Curve, such as with a flywheel storage system.

Flywheel Model

Definition: A flywheel is a mechanical battery that stores electrical energy as kinetic energy and is commonly used in cars and older steam-based technology[2].

Goal: Build a small-scale proof of concept and determine efficiency of model with and without mass added.

Expectation: Increasing the mass of the flywheel will lead to an increase in the efficiency of the flywheel.

Testing Procedures

- Flywheel model was powered by a 9-volt battery for 15 seconds and connected to a voltmeter. After battery removal, we measured:
  - Rotations per second – Flywheel struck a playing card on the wall once per spin, and the audio file was analyzed
  - Electrical Energy (Joules) – The amount of electrical energy produced by the flywheel over time and measured with the voltmeter
  - Kinetic Energy (Joules) – The amount of physical energy that is being stored in the rotations of the flywheel mass over time, calculated using rotations per second
  - Efficiency & Energy Loss: The lower the energy loss of the flywheel, the higher the efficiency of the system as it is better able to retain and regenerate the energy stored within it.

Results

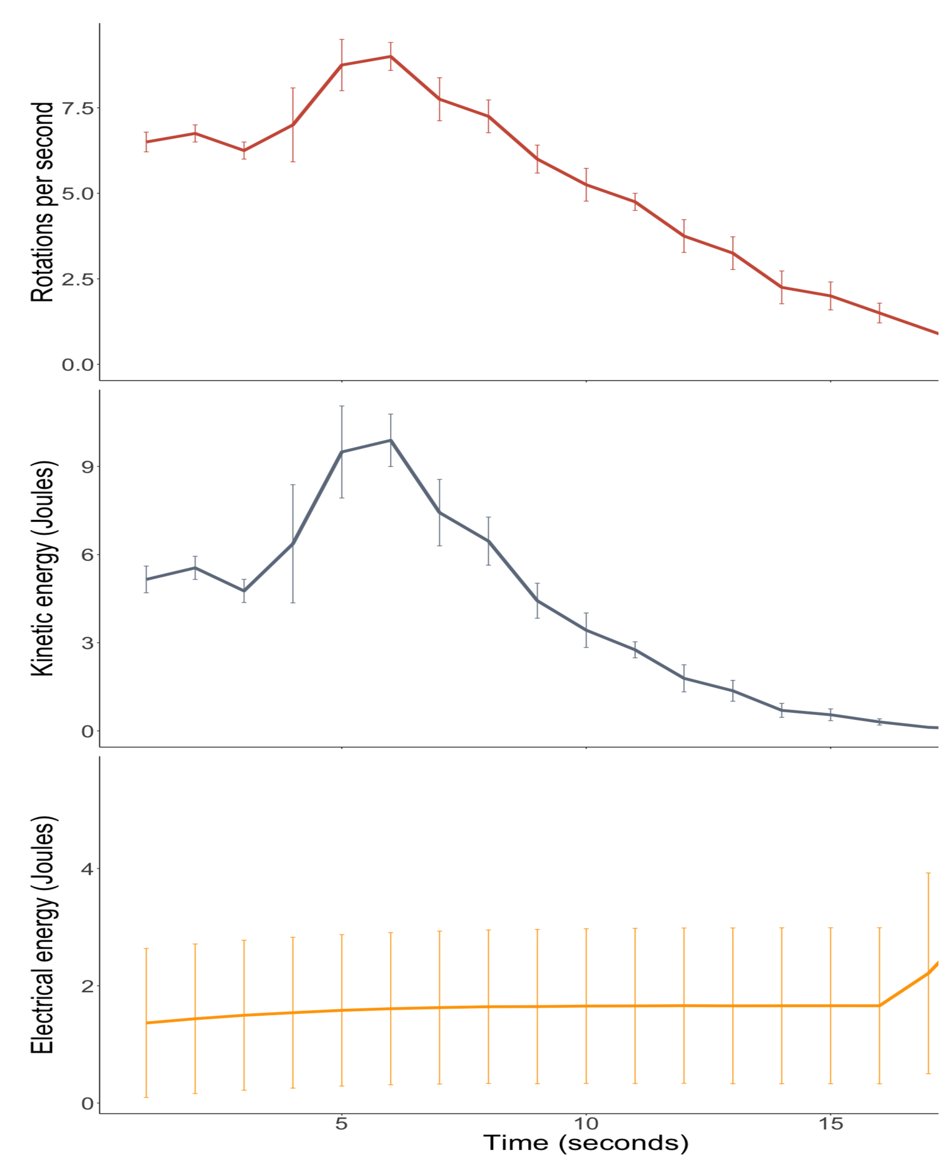

Figure 2. Flywheel trials with no additional mass appears to experience less friction resulting in a lower amount of energy lost.

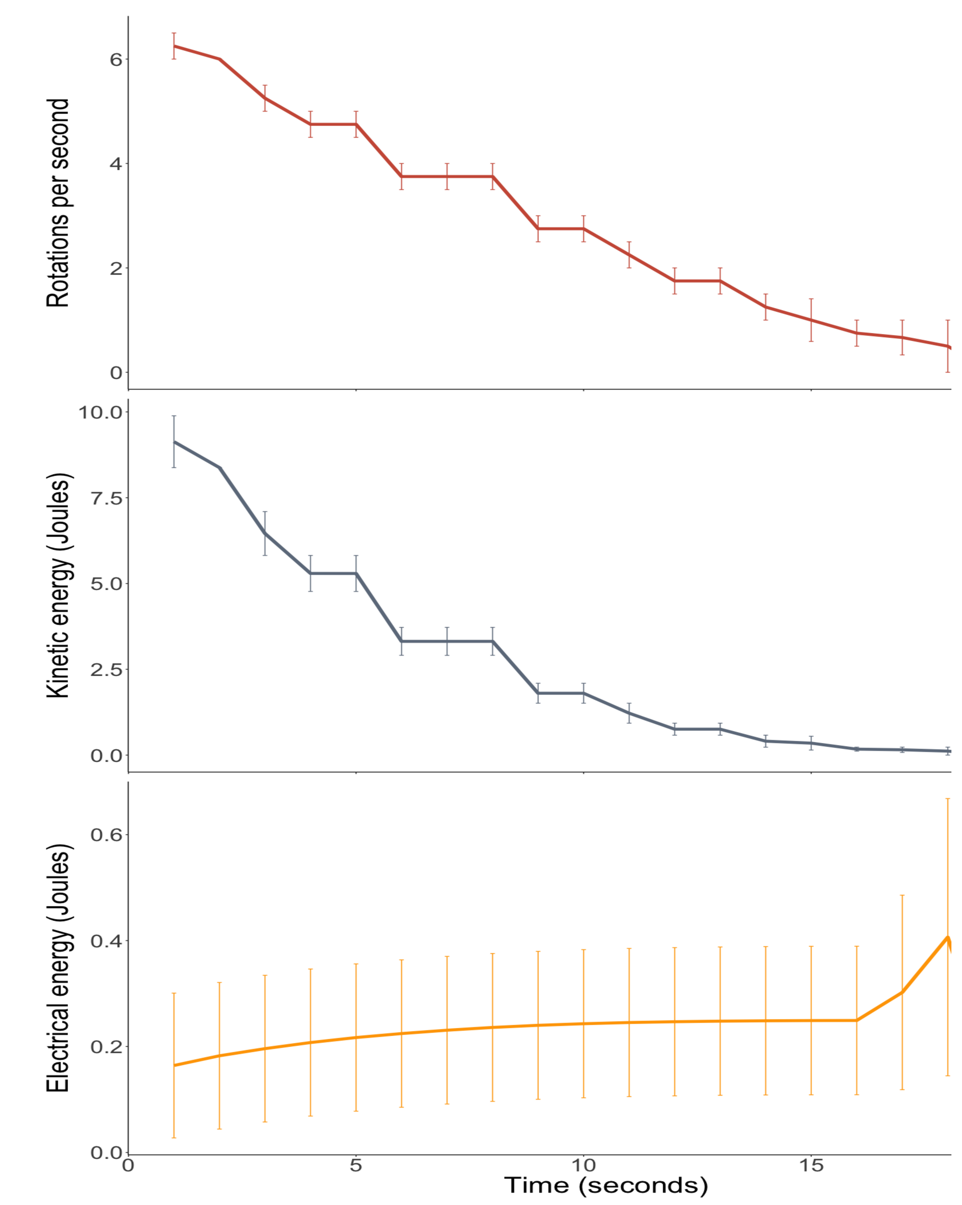

Figure 3. Flywheel trials with additional mass causes quicker decline in energy loss due to increased friction on the system.

Table 1.

- Energy Loss (%): Represents the total amount of energy lost in the flywheel, and indicates the flywheel's efficiency
- E->KE Loss (%): Amount of energy lost from transferring energy from the electrical system to the spinning mass
- KE->E Loss(%): Amount of energy lost from transferring from the spinning mass to the electrical system.
- Other Losses (%): Energy losses from friction and heat generated by the motor

Mass (g)	201.62	386.62
Energy Loss (%)	97.71%	99.62%
E->KE Loss (%)	77.69%	83.18%
KE->E Loss (%)	88.87%	97.89%
Avg. Transfer Loss (%)	83.27%	90.54%
Other Losses (Friction, Heat, %)	13.83%	9.08%

First Flywheel prototype built from a repurposed mop bucket.

Updated flywheel model with 3D printed parts

Conclusions

- Friction is a severe barrier to the model flywheel, leading to high energy loss regardless of additional weight
- Additional mass reduced efficiency likely due to increased friction between the rotating mass and the generator
- For large scale applications, barriers of friction and transfer losses will be most important to address

Future Work

- Test flywheel in a vacuum to determine if friction was the main source of reduced efficiency
- Attempt to scale up model to work with a small solar panel to provide testing in a more realistic setting

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References

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2. Bolund B, Bernhoff H, Leijon M. 2007. Flywheel energy and power storage systems. Renew Sustain Energy Rev. 11(2):235–258. doi:10.1016/j.rser.2005.01.004.