Unlocking the potential of electric and hybrid tractors via sensitivity and techno-economic analysis

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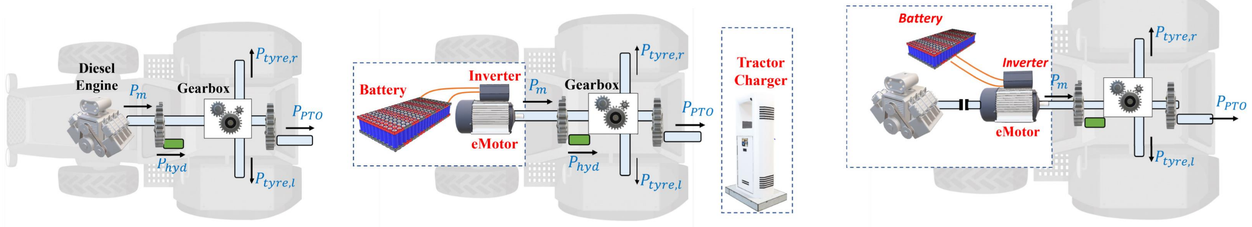
ABSTRACT

Almost all agricultural vehicles currently in use still rely on fossil fuels and diesel-based propulsion, one of the main sources of air pollutants. Electrification is the long-term solution to decarbonize agricultural vehicles. However, the road toward full electrification is challenging: the first generation of battery-based electric tractors has higher purchase price than diesel counterparts, requires additional investments in charging infrastructure and suffers from reduced number of working hours per charge. To address this challenge, we develop techno-economic models to evaluate the total costs of ownership (TCO) of electric tractors.

MOTIVATION AND GOAL

Diesel | **Electric** | **Hybrid**



Tractors under consideration:

- Three types of tractors: Diesel vs Electric vs Hybrid
- Assumption: all tractors employ the same mechanical (rear wheel) transmission system
- Motor provides tractive power to the tractor's tires ($P_{tyre,r}$, $P_{tyre,l}$), hydraulic sub-system (P_{hyd}) and PTO.

Research Questions:

- Can electric powertrains be more affordable than diesel over the tractor's lifetime?
- If yes, under what operating conditions?

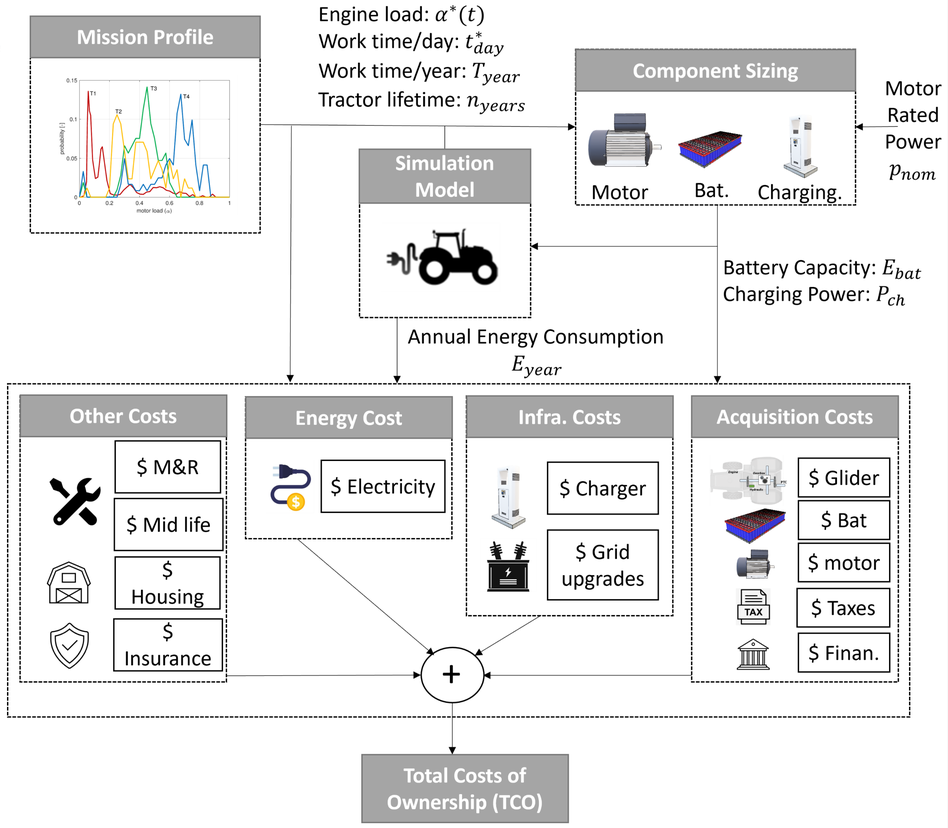
METHODOLOGY

- ***Step 1***: define the operational requirements and mission profile for the tractor, including work intensity (i.e., engine load), operating hours
- per day and year and
- the tractor's expected
- lifetime.

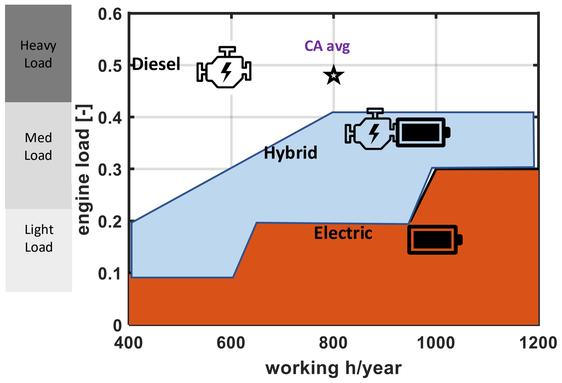
- ***Step 2***: determine the
- size of the tractor components, e.g., capacity of the battery
- and charging power, capable of satisfying the mission profile.

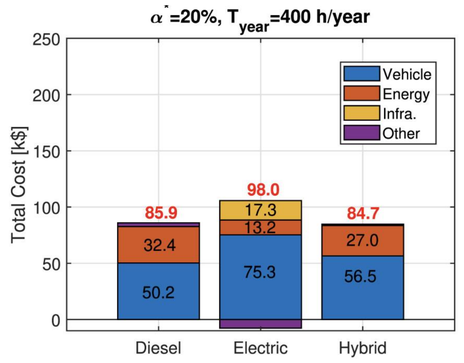
- ***Step 3***: predict the
- energy consumption of the electric tractor using
- a numerical simulation model (MATLAB-Simulink)

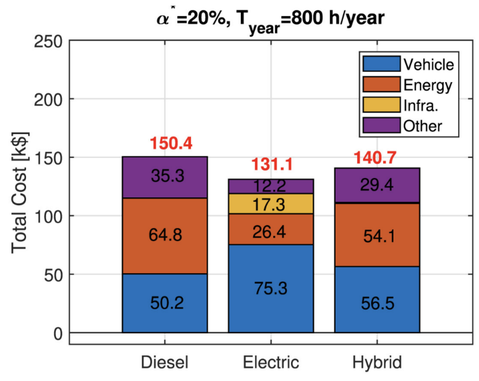
- ***Step 4***: Evaluate total costs of ownership of the tractor (cost of purchase, infrastructure,
- energy, …)

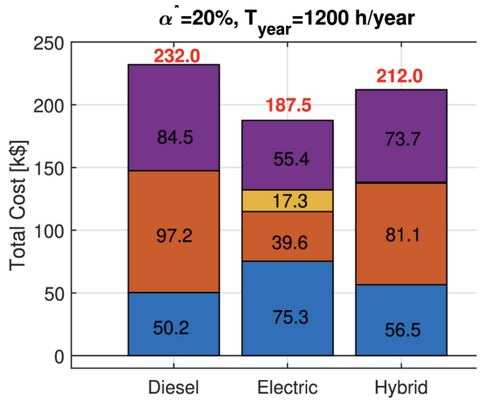


RESULTS: DIESEL VS ELECTRIC VS HYBRID

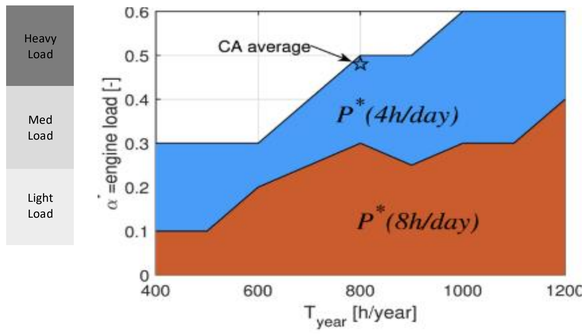


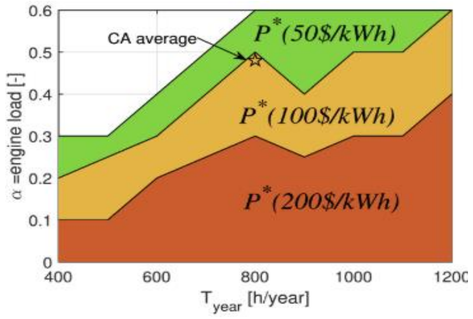


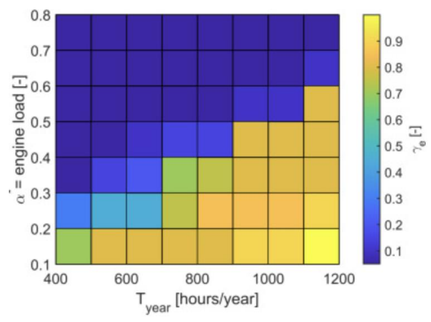


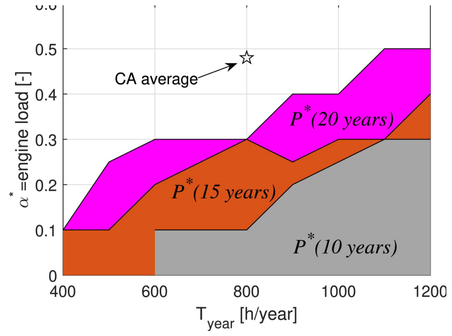


SENSITIVITY ANALYSIS









CONCLUSION & OUTLOOK

- We developed a techno-economic tool that can help the agricultural industry understand the overall total costs of ownership (TCO) of battery-based electric tractors
- This tool can be useful for engineers, policy makers and farmers who are currently planning electrification of farming fleets and need practical techno-economic tools to guide their future investments

Electric Tractor

- **offers many opportunities:** air pollution, energy efficiency, noise, M&R, …
- **"pays off" for light loads**
- **as battery prices drop to 50$/kWh:** cost parity with diesel tractors in a wide variety of operating conditions will be achieved

Hybrid Tractor

- affordable option for **medium loads**
- good **balance between costs & emissions for heavy loads**

Future work:

- Make decision-aid tool available to farmers to help them decide the best type of tractor powertrain
- Include new features to the decision-aid tool: farming fleets, more types of powertrains (e.g., fuel cells)

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