DEVELOPING AN UNDERSTANDING OF THE COSTS OF MANUFACTURE FOR LI-S BATTERIES

Development of analysis methods used to investigate the commercialisation of Li-S batteries

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Introduction and Abstract

- From an academic and industrial standpoint, there has been an increase in interest in Lithium-Sulphur (Li-S) batteries over the past 20 years. This has resulted in significant advancements in technology, implying that the commercialisation of Li-S is closer than ever[1],[2]
- Outstanding challenges of the Li-S battery include a relatively short lifetime when compared to mature technologies, compounding sulphur's low electrical conductivity, and volumetric expansion caused by cycling[3], which has hampered widespread adoption
- A techno-economic analysis of the possible impact of Li-S batteries was carried out in this work by quantitatively analysing and comparing the financial data of Li-S focused businesses using a cost model. As a result, I adapted a mechanism to determine the anticipated costs of manufacturing Li-S Batteries, which could materialise as the cell format evolves over the coming years.

Motivation

- Batteries that surpass the energy density of Li-ion technology will be necessary to enable the widespread electrification required to achieve the global net zero goals. The most promising of these technologies is conceivably Li-S, which offers practical energy densities between 300 and 550 Wh/kg along with a theoretical energy density in excess of 2654 Wh/kg[1]. The current generation of the technology, is likely to be suitable for several early adopting markets, including unmanned aerial vehicles and pseudo-satellites[2]
- This work aims to offer an early insight into the commercialisation of Li-S batteries, including the cost of producing a Li-S battery using recent advancements in the synthesis and manufacturing processes of Li-S battery technology. A viewpoint on the market and its potential commercialisation was presented. This research can be used to direct Li-S battery development efforts by highlighting the crucial technological advancements needed to produce a cell that is commercially viable

Methods

1. ***Python** was used to **translate** and **extract key data** from PDFs of Lithium Sulphur firms.*
2. ***Data** was collected on **manufacturing, production,** and **raw material costs**, along with other metrics.*
3. *This **data** was then **analysed** using a modified **battery sizing and price model.***
4. *We determined the **impact** of each cell on the **cost** of **production, energy density,** and **life cycle**.*
5. *The **optimal cell** was then **determined** by **comparing** these **parameters** to one another.*

Results

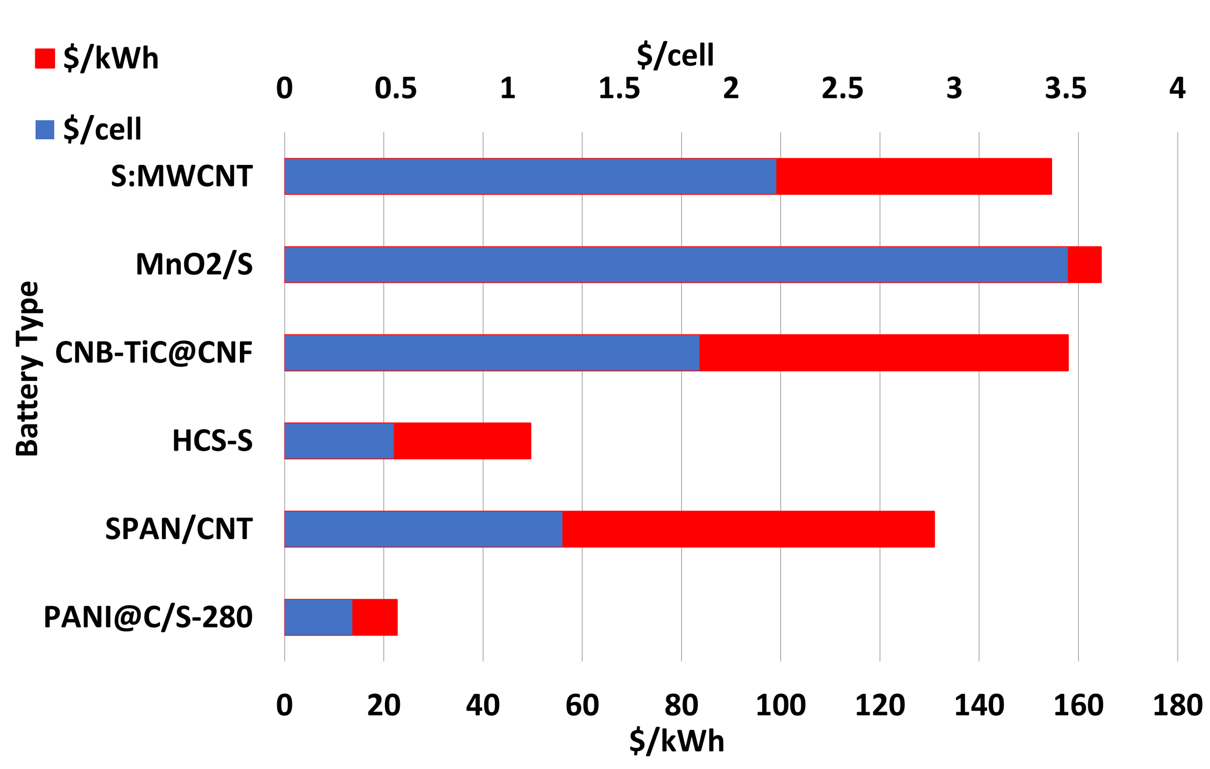

Figure 1. Shows the Cost per cell and cost per kWh of various Li-S cells.

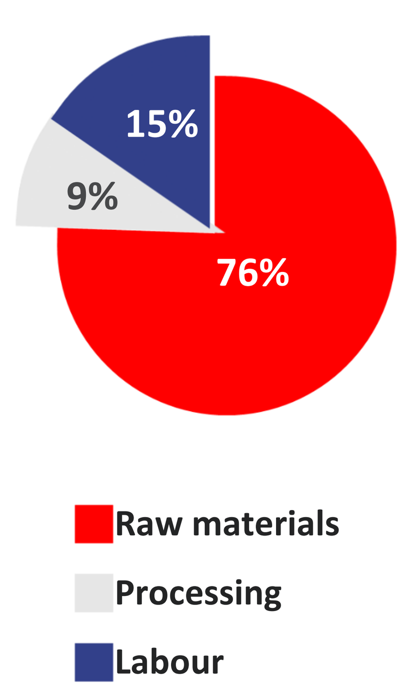

Figure 2. Depicts the breakdown of the average cost of a Li-S cell.

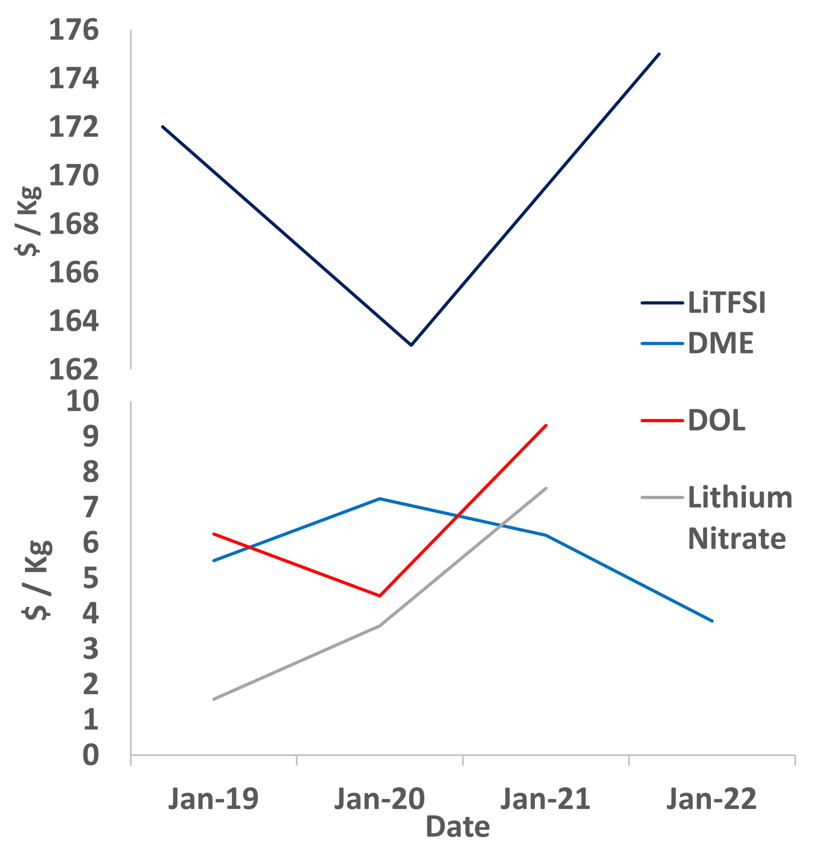

Figure 3. Displays the spot price across three years for the most popular electrolyte system.

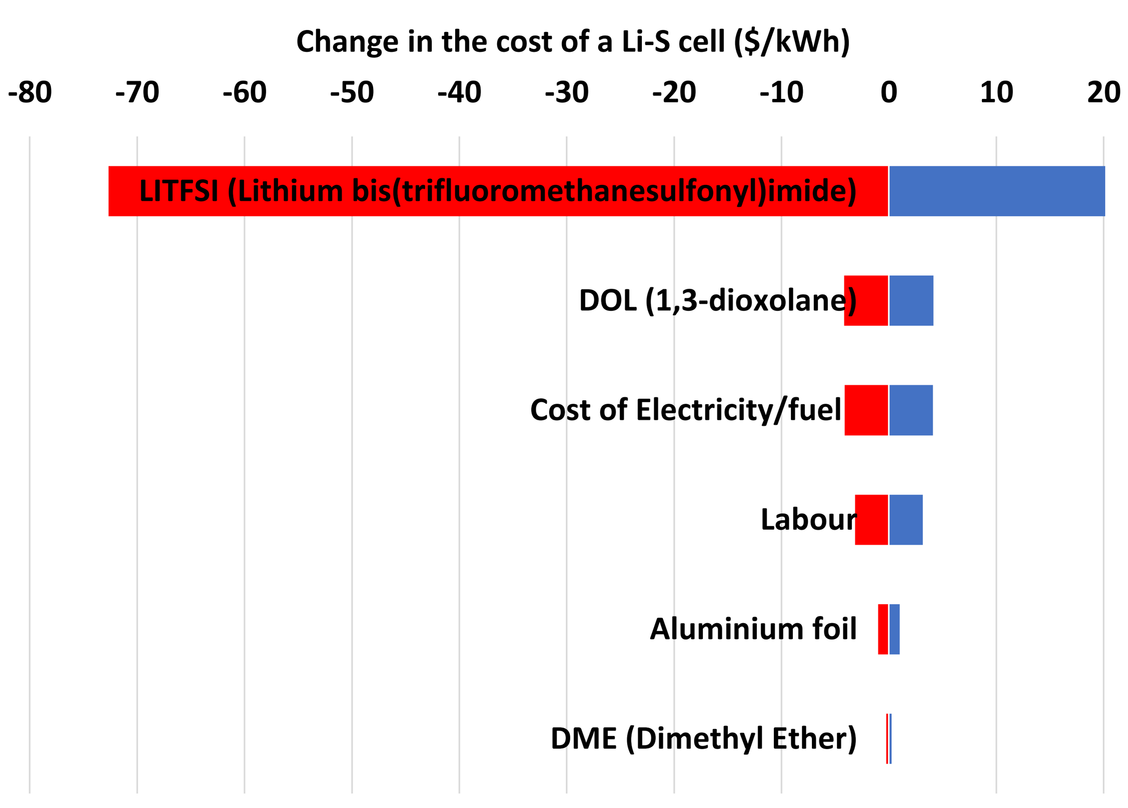

Figure 4. The tornado plot illustrates how a 25% increase or decrease in the cost of the cell would affect the cost.

Results

- **Figure 1** depicts that **PANI@C/S-280** has the **lowest production costs** on **both a cell and energy basis**. Based on the **$/kWh** metric the **CNB-TiC@CNF cathode** provided one of the **highest costs**; however, the cell has amongst the **highest energy densities** which suggests it is **best deployed in high-value applications**
- **Figure 2** illustrates that the **raw materials** were the **most expensive portion of the cell**, accounting for **approximately 76%** of the **total cost of the cell**. While **Figure 3** shows that **LiTFSI** is the **most expensive raw material in the electrolyte**, **reducing** the amount of **LiTFSI** would greatly **reduce** the **cost of the cell**. **Figure 4** shows that reducing the amount of **LiTFSI by 25% reduces the cost of the cell** by **>$70/kg**, making a Li-S cell much more viable and appealing commercially
- Figures 1, 2, 3 and 4 provide valuable information in determining whether a cell is viable or not; however, **other factors such as life cycle, safety, scalability and potential operating temperatures** of the Li-S battery **should be considered** when **deciding if the cell is worth commercialising**

Conclusions

Due to their high energy density, lithium-sulfur batteries have a great deal of potential to capture the market. Based on this study several conclusions of the cell's studies can be obtained:

- The commercialisation of carbon nanotubes (CNTs) containing cathodes is likely due to their affordability and light weight. When compared to the system's weight, S:MWCNT and SPAN/CNT are both inexpensive. S:MWCNT and SPAN/CNT achieved 387.82 and 347.78 Wh/kg, respectively, which is promising for Li-S cells and supports their scalability
- Lithium is an expensive raw material, and its price will increase significantly over the next ten years due to mining issues brought on supply issues and lack of investment. Consequently, the cost of the producing Li-S cells has increased
- $/cell and $/kWh are important indicators for comparing cells, but they do not provide a whole picture when determining whether a cell is commercially feasible; instead, factors such as life cycle and operating temperature should be considered

Impact / Next steps

- The Exawatt team, in collaboration with LiSTAR, and the Faraday Institute, aspires to advance both existing technology and investigation techniques used to examine the commercialisation of Lithium-Sulfur batteries
- The potential of economically and environmentally friendly commercialisation of Lithium-Sulfur batteries and their potential use was highlighted
- The Faraday institute and LiSTAR to provide further funding and research opportunities in this area of research

References and Acknowledgments

Thank you very much to James Robinson of UCL and LiSTAR and Simon Price, Ed Rackley and, Aaron Wade of Exawatt for their continued support along this internship.

1) *J. Phys. Energy, 2021, **3** 031501*
2) *Small, 2022, **18(21)**: 2200326.*
3) *Energy 2020, **201**, 117718,*
4) *J. Mater. Chem. A, 2015,**3**, 10760-10766*
5) *Adv. Funct. Mater, 2019, **29**, 1902929*
6) *Adv. Funct. Mater, 2013, **23**: 1076-1080*
7) *J. Mater. Chem. A, 2020,**8**, 11327-11336*
8) *Ionics, 2020, **26**, 4853–4857*

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INTERN BIO

Aran Wellman, a third-year chemical student at the University of Birmingham, intends to pursue a master's degree in Material Chemistry.

His research interests include the development of lithium-ion battery alternatives, as well as the advancement of existing lithium-ion battery recycling and upcycling techniques. Furthermore, his enthusiasm extends beyond academia, and he wishes to inspire the next generation of chemists.

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