Technical constraints that affected the validation of the technology, the solutions found and the lessons learnt.

There were four technical constraints that affected the validation of the technology: cell frames production, ohmic losses, polarization losses and shunt current losses, being the last one the one that had the highest impact.

- The reception of plastic cell frames suffered a delay of 5 months because of a nonstandard design and the selection a proper manufacturer was especially difficult. Two main problems arose: the volume of the order was relatively small for all the specialized companies and machining of polymethylmethacrylate (PMMA's) plates was troublesome as the standard conditions for machining produced a deformation in the plates. The new method relied in a slower movement of the mechanical tools to avoid the heating of the polymer, so the manufacturing of the frames consumed three times longer than expected. **New materials as ABS (acrylonitrile butadiene styrene) and new fabrication methods (laser sintering, fused deposition modeling) and external manufacturers are being tested to manufacture cell frames of the new battery that TR is developing.** For industrial production of the cell frames for a future industrial scale energy storage plant injection of ABS has been identified as most suitable technology.

- Voltage efficiency was lower than expected due to **ohmic losses** in the cell interconnections. The difference between 0.82 kW (real) and 1kW (expected) came from the ohmic losses on every cell (6 mOhm) that were higher than previously calculated. The same explanation is valid for the difference between the expected and the achieved energy. **Ohmic losses can be reduced by using connections with less resistance (thicker cables)**

- **Shunt currents** are driven by the potential difference between the cells of a stack, electric currents flow over the conducting electrolyte connections reducing energy efficiency. During charging, effective current density is higher in the external cells and, during discharging, the current that effectively discharges the external cells is lower. Therefore, zinc accumulates in the external cells producing short-circuits. Shunt current losses can be reduced by improving the stack design. **Increasing electrolyte path resistance and connecting cells hydraulically in series have been found to be effective ways of reducing these losses. Both solutions are currently being implemented in the new battery development carried out by TR.**

- Individual zinc-air cell efficiency should be higher than 60% for the industrial plant to be technically and economically viable and competitive with other storage

technologies. Individual cell losses are mostly due to **air electrode polarization losses**. Increasing the efficiency to 70-90% only seems feasible in the medium term to long term, considering the performance of state-of-the-art of oxygen catalysts used in the air electrode.

OTHER

- Large battery stacks with cells connected in series produce high voltage outputs (at least over 24 V). Most commercial analog input modules do not accept common voltages higher than 10 V and anomalous reading of the separated voltages of each cell can appear, as it happened in ZAESS project. **Specific battery monitoring analog input module has been found and has being tested to monitor cell voltages in the battery stack.**

- Auxiliary systems (such us pumps, compressed air…) have a huge impact in the efficiency of the zinc-air technology. **This impact have been quantified thanks to ZAESS project and it is trying to be reduced by two methods: reducing the electrolyte flow needed to increase zinc electrode efficiency (improving zinc electrode by other means like additives) and stopping the pump during battery discharge.**

- Labor cost has a big influence in the operating costs of the plant, reducing the profitability and compromising the viability of the technology. **An automated and modular solution is being implemented for the new battery design.**

- Website and workshops were very effective ways to disseminate the project whereas oral presentations made in specialized conferences, in our own experience, were less effective. **Workshops attracts potential clients whereas specialized conferences are too academic and less commercially oriented.**