The Nobel Prize winner Pierre-Gilles de Gennes allegedly once said of nuclear fusion, “We say that we will put the sun into a box. The problem is, we don’t know how to make the box”. Here lies one of the most important materials-science challenges of the 21st Century. It is vital to remember that although renewables like wind, hydro and solar can fulfil much of our needs, the only option we have for uninterrupted baseline electrical power will come from nuclear. For the next generation of water-cooled fission reactors the problems are centred on two areas that are directly linked to the harsh environment, particularly the very high temperatures: corrosion and stress corrosion cracking. Producing materials that can operate safely under such conditions – not only in nuclear reactors, but in many other fields where extreme conditions are encountered – is a very pressing concern.

The scientific goal of the project is to examine whether an ultrasonically gas-atomised precursor steel powder or a steel powder with smart surface oxidation in combination with one of two new consolidation techniques – selective laser melting (SLM) and pulse plasma sintering (PPS) – can impart oxide-dispersion-strengthened (ODS) steel with better performance in extremely harsh, high-temperature conditions. The current best-performing ODS steels have tensile strengths up to almost 800 MPa at 600 °C, compared to over 1200 MPa at room temperature. The rapid fall of in performance as things get hot can be traced to the uneven distribution and clustering of the dispersed oxides in the microstructure of the consolidated steel component. Our aim is to disperse precipitates of $Y_2O_3$ and $TiB_2$ much more evenly in the precursor powders by tuning the ultrasonic parameters of the gas-atomisation process to create the maximum extent of dispersion prior to consolidation. The powders will then be either selectively laser melted or pulse-plasma sintered, before being assessed microstructurally and for their mechanical resilience and resistance to corrosion at very high temperatures. The results will be benchmarked against conventionally produced, mechanically alloyed powder that is consolidated using spark-plasma sintering (SPS). To test the hypotheses delivered in this project, the project outline includes a number of possibilities, and they are graphically shown in Fig. 1.

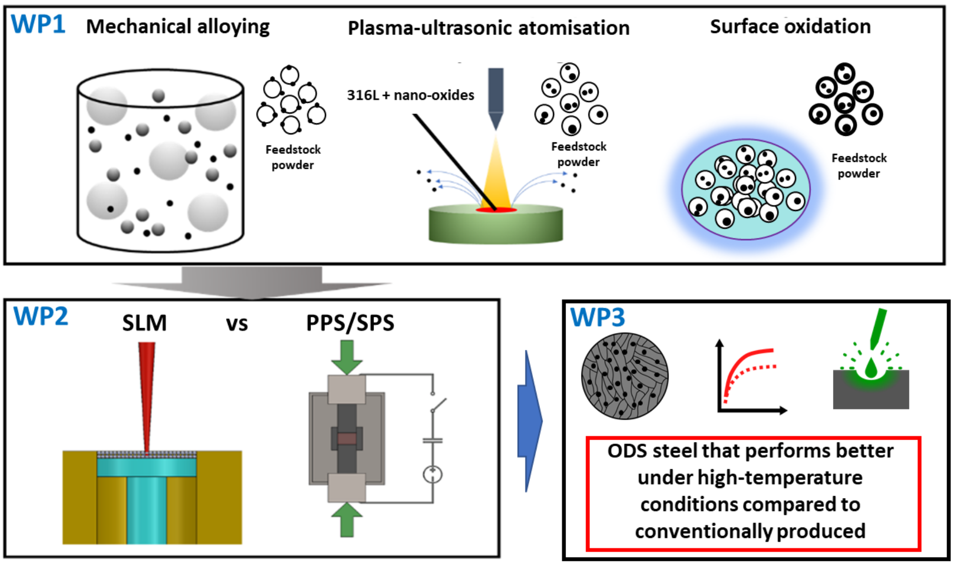

**Figure 1**. Graphical abstract of the project.

The proposed research project is extremely relevant from the basic research point of view, as it will bring about a much better fundamental understanding of the parameters influencing the manufacture of ODS steels using powder metallurgy routes. SLM is a process that will allow us to re-melt the feedstock powders, build a geometrical structure, during which the rapid melting and solidification will ensure the precipitates will appear. We believe that a homogeneous distribution of oxides will result from the local mixing of the melt and the subsequent rapid solidification. Moreover, we will generate new knowledge about manufacturing uniform microstructures with spark-plasma sintering (SPS) and pulsed plasma sintering (PPS).