



Contribution ID: 145

Type: **not specified**

# 4th Generation High Energy Synchrotron X-rays at the ESRF: A Pivotal Large-Scale Tool with Socio-Economic Benefits

*Thursday, 16 November 2023 14:00 (30 minutes)*

The European Synchrotron (ESRF) has recently completed its upgrade to become the world's first fourth-generation high-energy synchrotron X-ray source, serving nearly 10,000 researchers annually. The ESRF holds a prominent position on the European Strategy Forum for Research Infrastructures Roadmap and is recognised as a central pillar of the European Research Area. The exceptional brilliance and unique properties of the ESRF's X-rays open new avenues for scientific research, leading to emerging applications for a growing user base.

Recent ground-breaking research conducted at the ESRF has had wide and novel socio-economic impacts. For example, multiscale imaging of human organs has revealed unprecedented insights into disease mechanisms. These results are accessible through "The Human Organ Atlas" ([human-organ-atlas.esrf.eu](http://human-organ-atlas.esrf.eu)), an open science and FAIR data resource available to all. This resource is being utilised for medical education, providing valuable insights and improving clinical diagnostics for medical scanners. The ultimate goal is to create a comprehensive micron-scale human model.

Other examples include research on battery safety and design, utilising ultra-high-speed X-ray radiography and specific containment for real-time destructive battery testing, as well as high-throughput structural analysis in collaboration with an industrial partner to provide data for materialomics.

Worldwide, there are approximately 30 medium and high-energy synchrotrons. Building on the pioneering work of the ESRF, more high-brilliance synchrotron sources are planned globally, promising further advancements in the remarkable science produced by these facilities. Moreover, many countries and regions without direct access to a synchrotron are actively pursuing scientific, technical, and socio-economic justifications for establishing such facilities, recognising their broad utility and impact.

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**Session Classification:** Plenary

**Track Classification:** AfLS