Horizons of energy storage:

Emergent leaderships,

Key-characteristics, and

Development pathways

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RGIT

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1) Integral to modern economic life

2) Energy storage innovation

3) Tranformation toward circularity

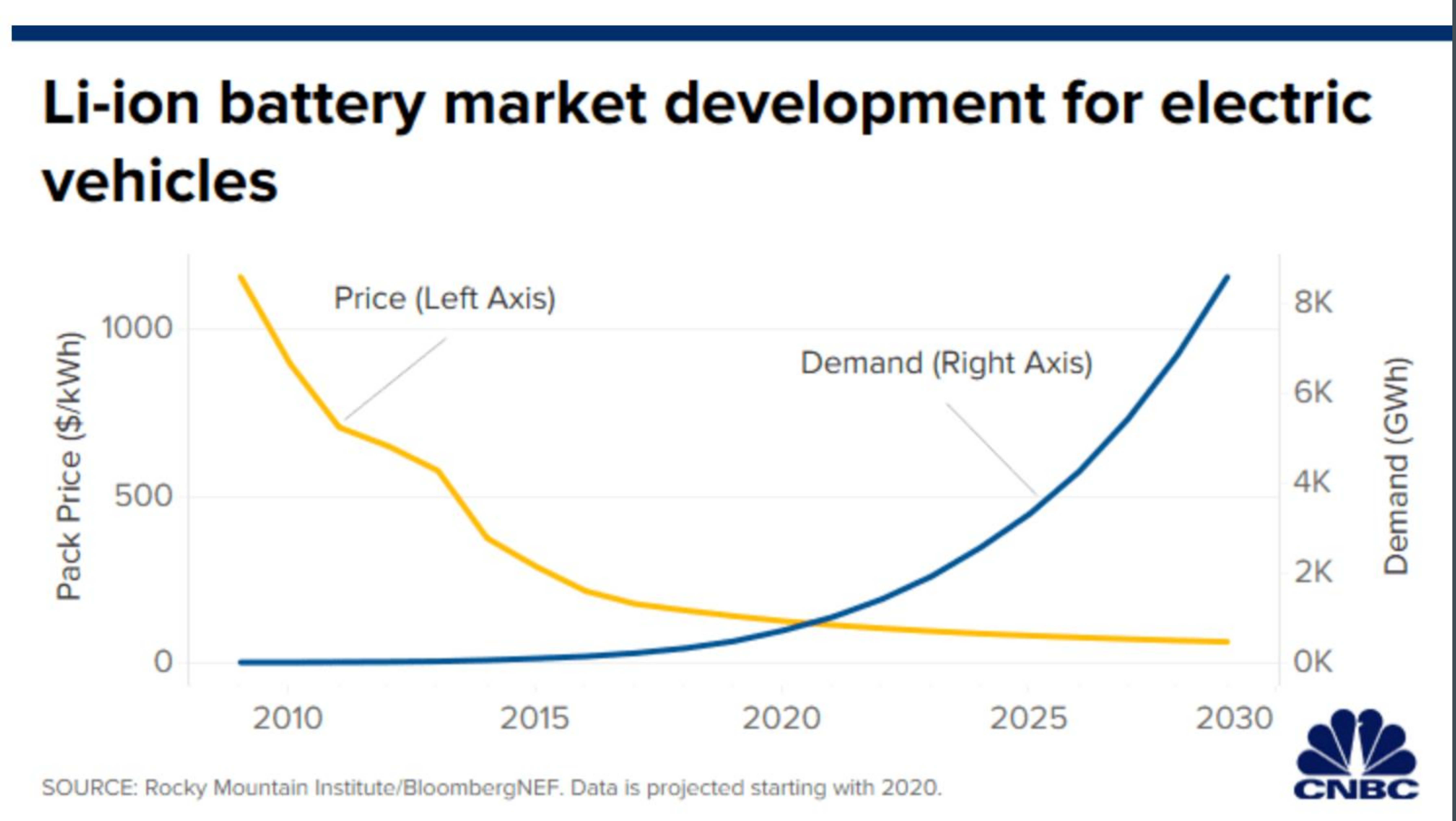
| Everywhere

Batteries integrating with more devices

Workers are seen at the production line of lithium-ion batteries for electric vehicles (EV) at a factory near Shanghai, China.

Reuters

Development is democratising deployment



| Innovation

Getting answers:

〉a big-data patent and in-text approach

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Battery innovation and the Circular Economy: What are patents revealing?

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ABSTRACT

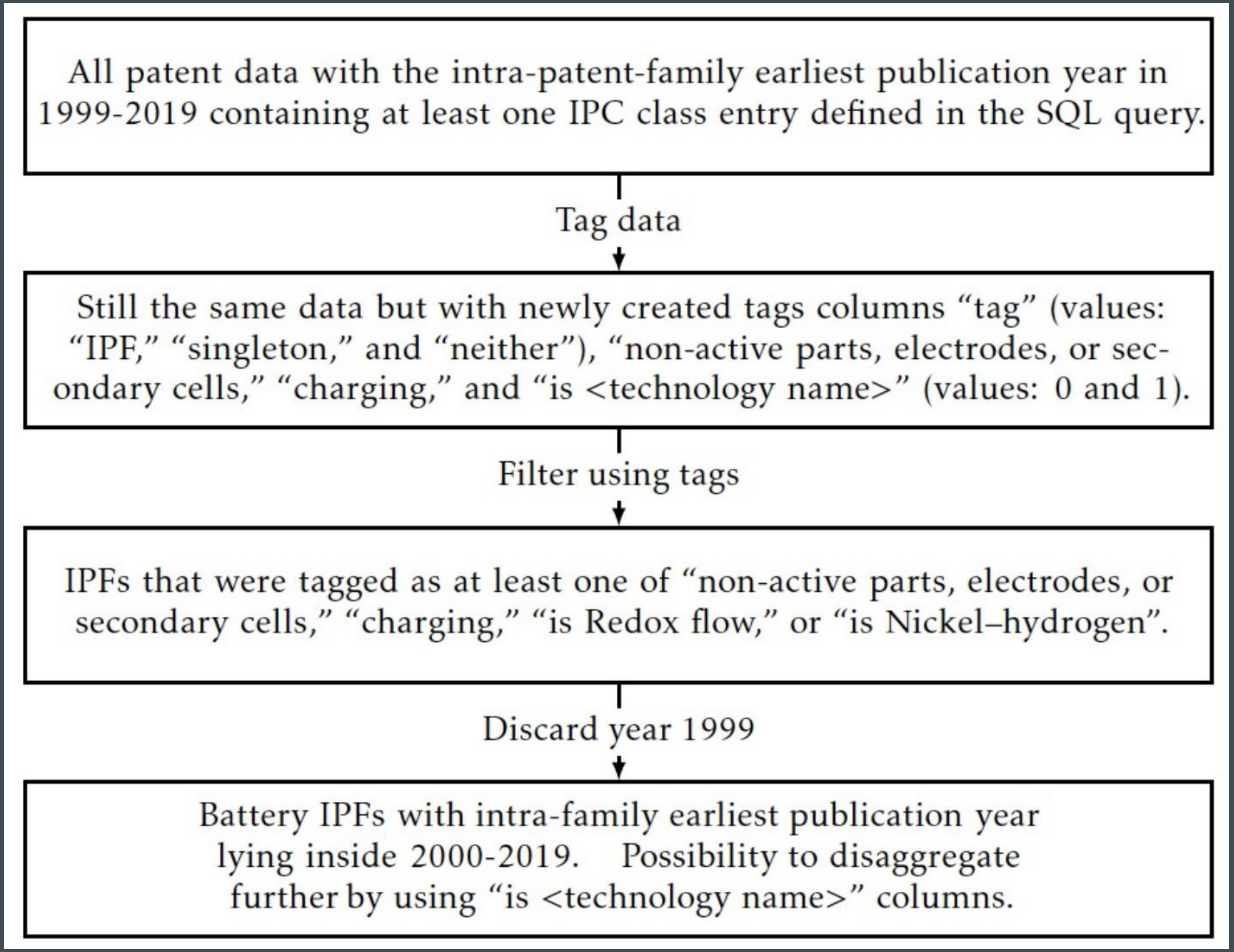
This analysis of over 90,000 secondary battery innovations (measured by international patent families) provides a comprehensive account of the long-run progress of a knowledge base with a key role in the transition to a transformative, closed-loop, Circular Economy. Innovation accelerated globally from 2000 to 2019, a sustained dynamic mostly originating in Asia. Patterns of less toxicity and more diversity in technological trajectories are detected and found to bear evidence of pro-circularity. We find a number of emergent technological trajectories, such as solid-state, lithium–sulfur, redox-flow and sodium-ion batteries, each one with a different potential to push ahead the circularity pathway, and which allow for the detection of country clusters. Through a methodology that can be of interest for further research, we examine the extent to which batteries have circular characteristics.

1. Introduction

Since the early days of the first Industrial Revolution in the late 18th century, global energy consumption has been on the rise [1]. Two centuries later, by the time the informational revolution was taking hold [2,3], the pressure was on to reduce CO2 emissions derived from the coal and oil paradigms that preceded it. New socio-technical compacts, from the Rio "Earth Summit" of 1992 to the Paris Agreement of 2015, have been fostering a holistic reform of social organization and of the energy sector in particular. To structure this process of change there is a growing need for new solutions in terms of power generation, distribution, storage, and upkeep. In this context, the Circular Economy framework has been proposed to reconcile economic and sustainable development [4,5].

The importance of batteries has been growing as a solution in a very dynamic puzzle. As a set of technologies at the intersection of the clean-digital transition, their role is expected to grow further in the coming decades [6]. A report about electricity storage developments published by the International Energy Agency (IEA) in association with the European Patent Office (EPO), asserts that "the level of deployment and the range of applicability of batteries [...] expands dramatically" in the foreseeable future [7, p. 28]. In particular, battery technologies will move beyond consumer appliances and into industrial-size types of equipment: "Charging batteries in electric vehicles will become the largest single source of electricity demand, accounting for around 5% of global demand by 2050" [7, p. 29]. Furthermore, "the use of batteries in stationary energy storage applications is [already] growing exponentially" [7, p. 32].

Identifying and monitoring the rate and direction of battery innovation as a condition for a low-carbon future is thus analytically worthwhile and strategically urgent. A growing body of empirical work has recently approached the battery industry from an innovation studies perspective (see [8–11]). Such studies stress how batteries represent a shift away from carbon-intensive technologies based on non-renewables (see also [12]) and symbiotic with post-industrial products, infrastructures and macro-societal models (see [13,14]). Indeed, this emerging patent-based literature has so far mostly dealt with the analysis of one or few batteries defined from a conventional electrochemical innovation perspective. In this paper, we stretch this line of work by providing a broad and long-run appreciation of secondary battery innovation while considering more explicitly how their technological content facilitates a deep transition toward circularity characteristics. In fact, batteries not only contribute to limiting CO2 emissions from fossil fuels, they also have systemically transformative effects. Whereas primary batteries are one-off assets, secondary batteries are rechargeable, i.e., these technologies are therefore intrinsically more pro-circular (vis-a-vis primary ones) since they have a longer and more flexible working life-cycle (the energy services extracted per kilogram of employed material are overwhelmingly superior). Thus,



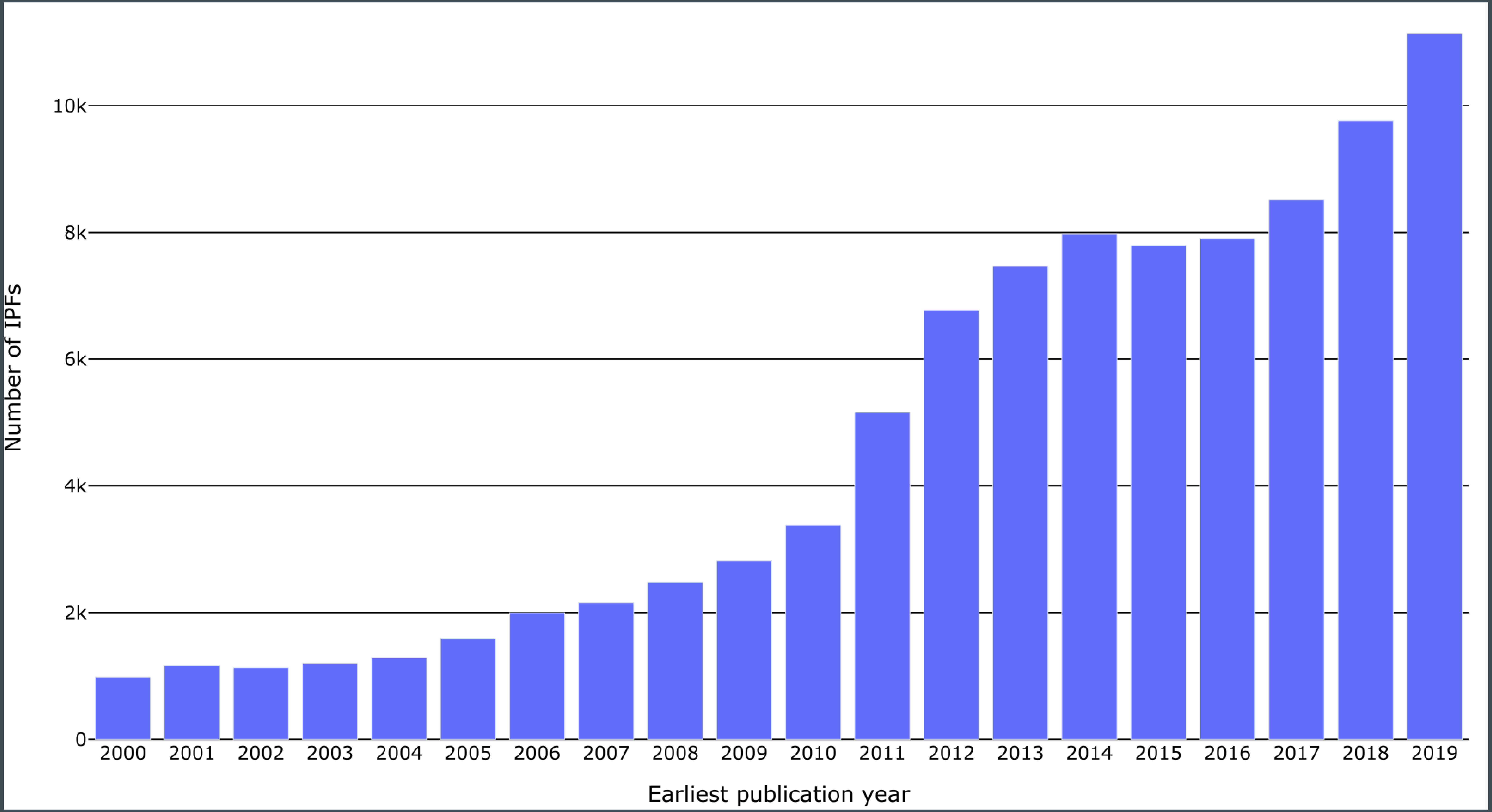
Source: PatStat

Period: 2000-2019

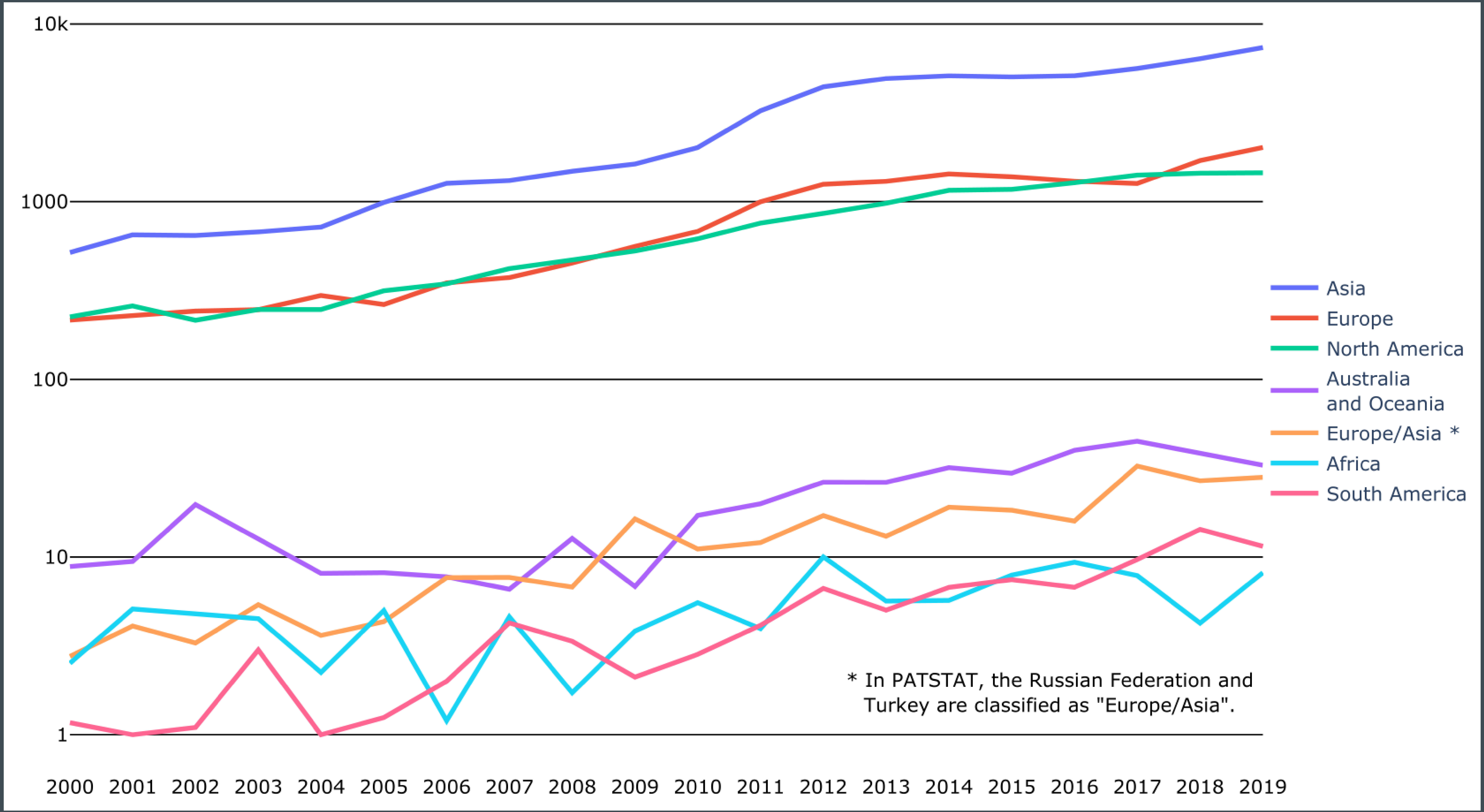
Patent familes

90k+

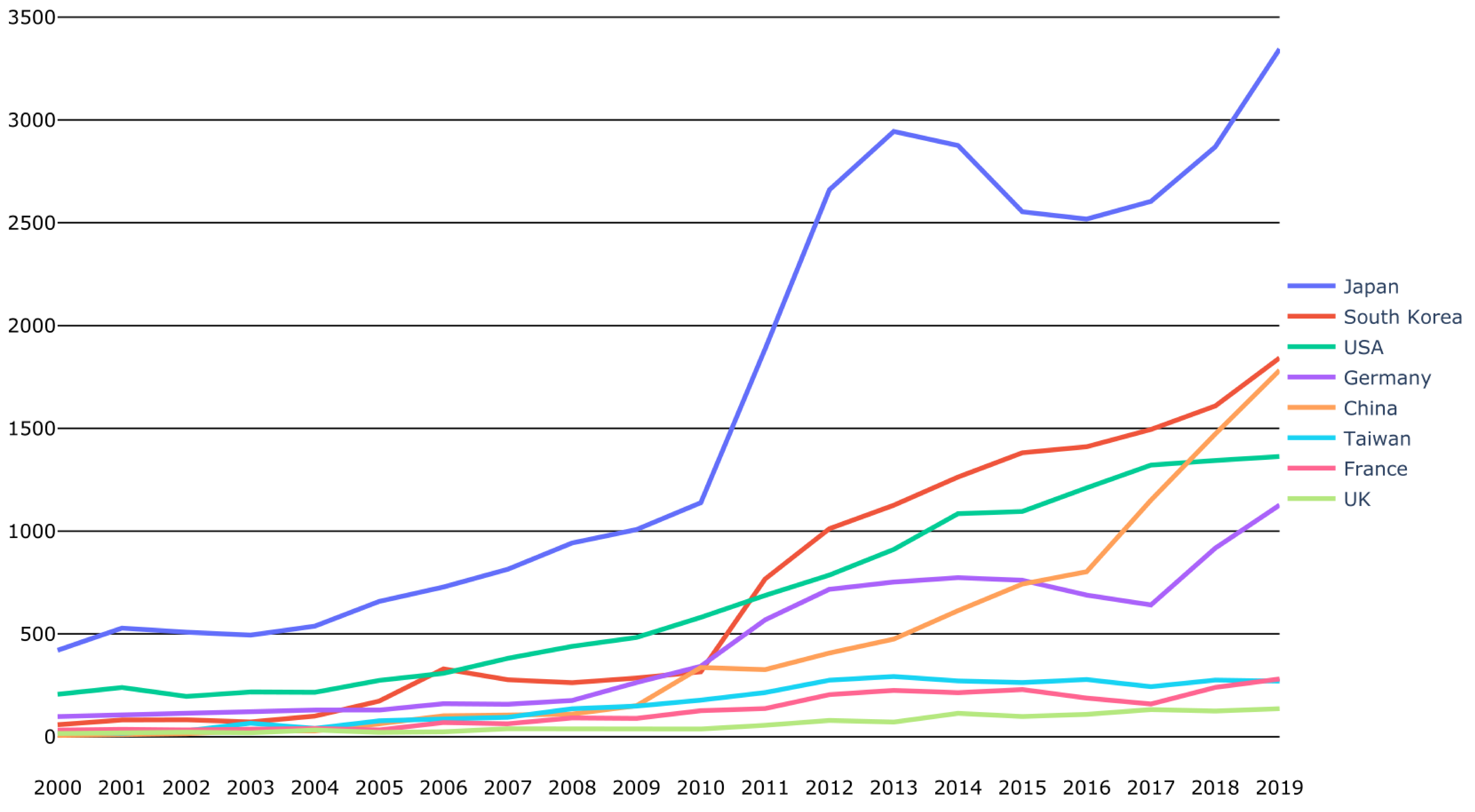
Growth and cycles



Batteries is an Asian game

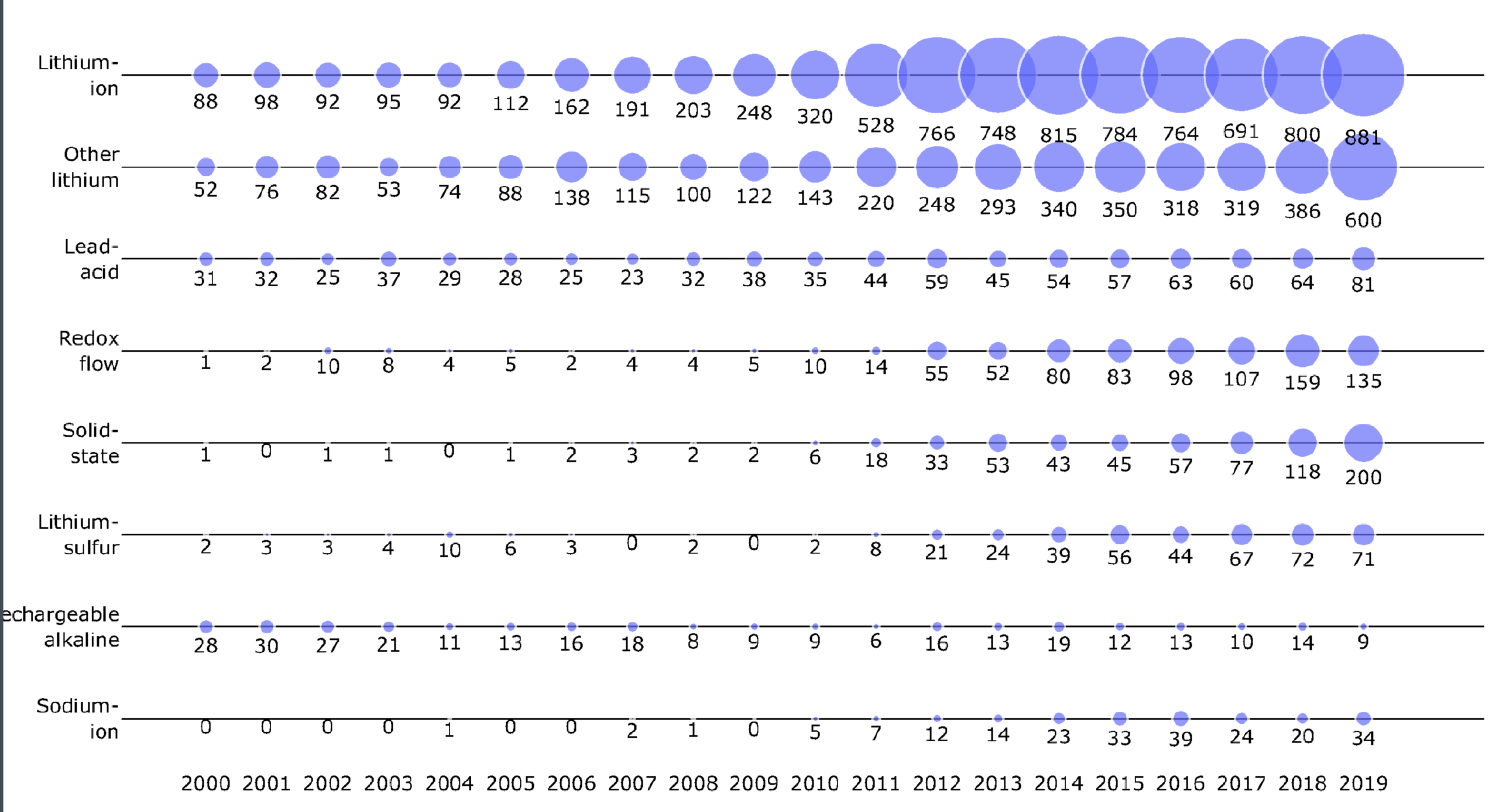


Competition increasing within Asia

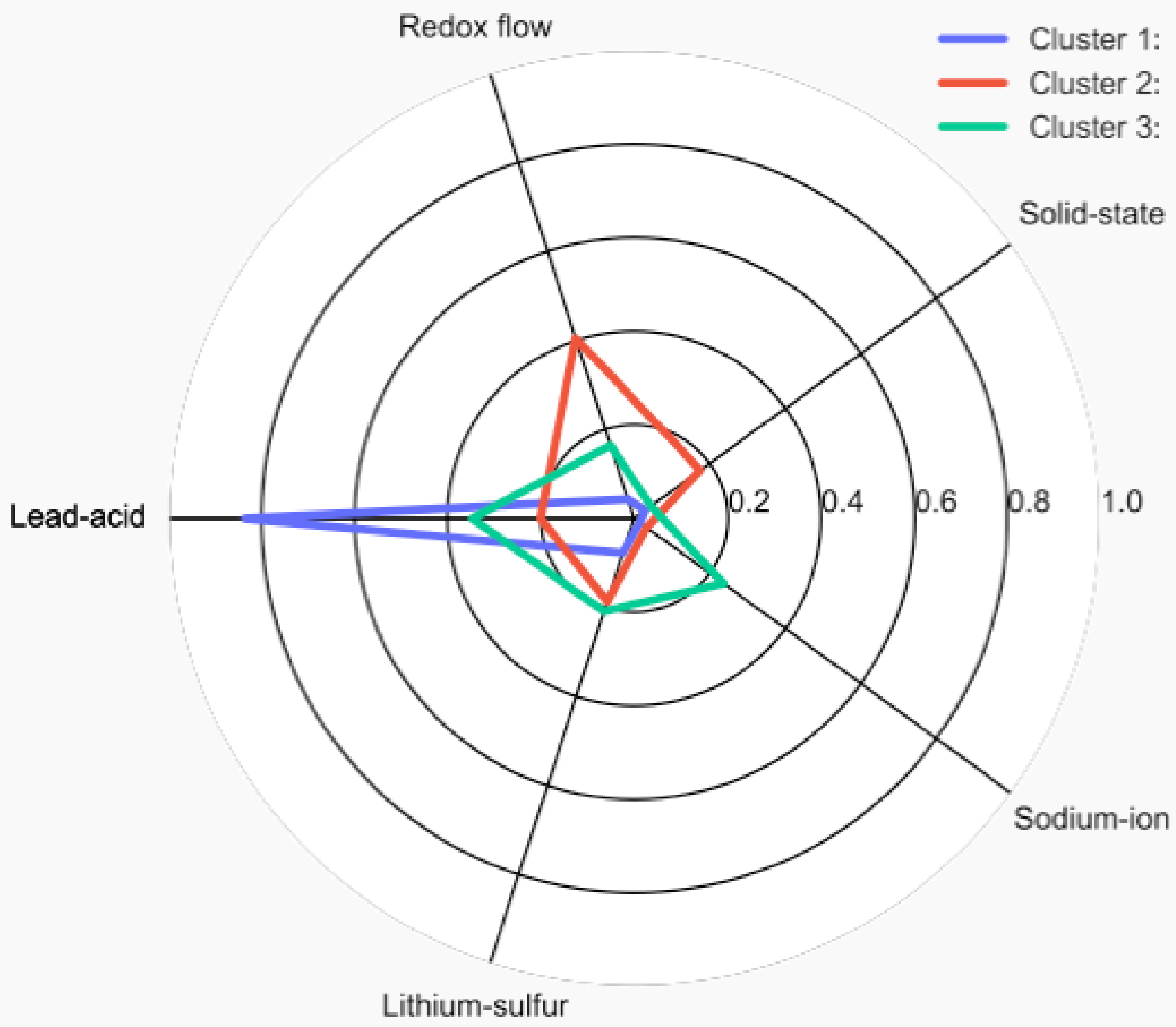


| Circularity

Portfolio is (slowly) restructuturing



Newst battery aveneues: three different country groups



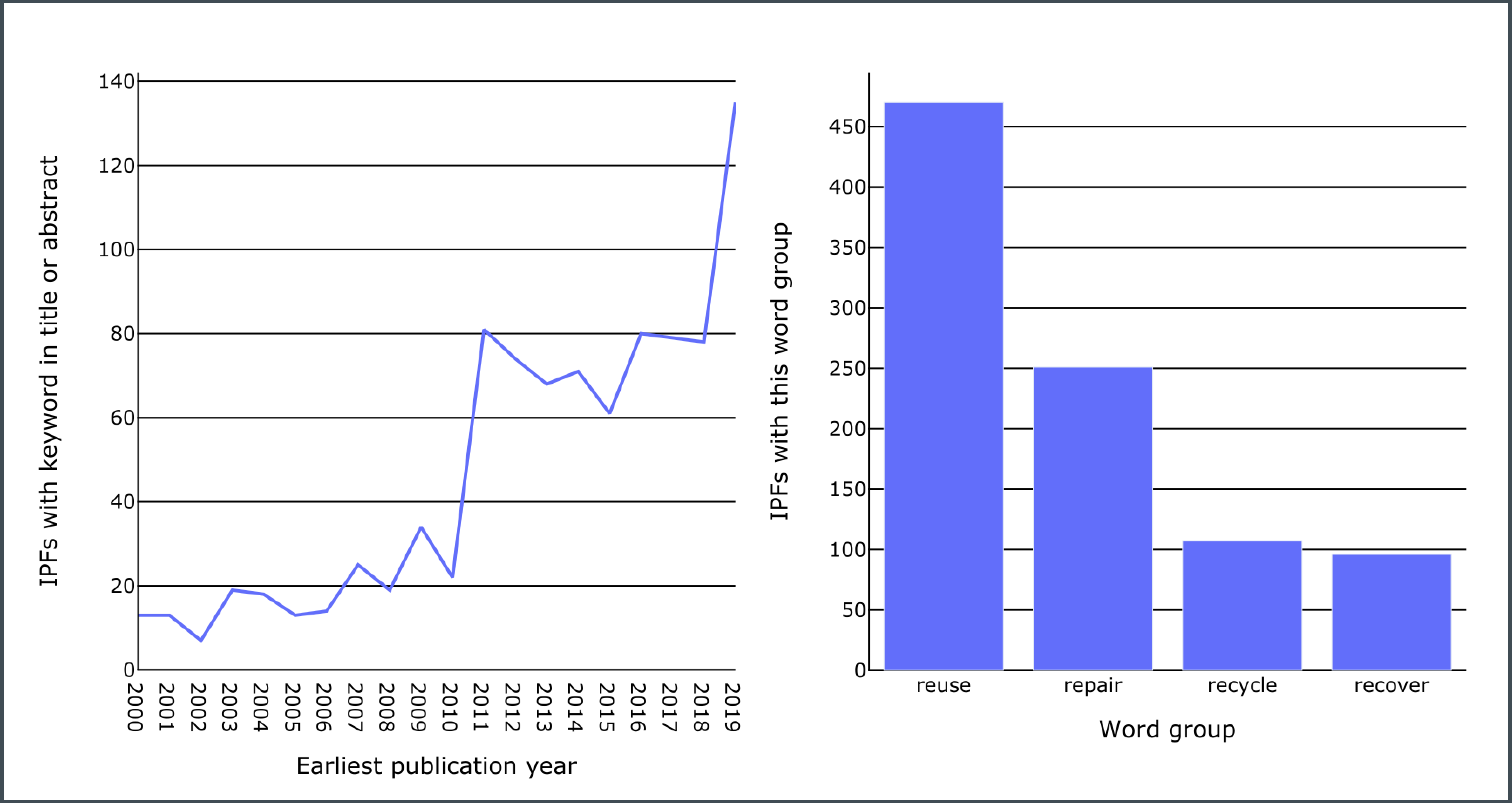
The three country groups differ

Cluster 1 (India, Israel, Turkey, etc.): specialisation in sun-set technology

Cluster 2 (South Korea, Japan, Italy, etc.): more technological diversification but strong emphasis on solid-state batteries (which is essentially a particular type of lithium-ion battery)

Cluster 3 (Canada, China, France, etc.): robust innovation activity in three emerging technologies outside the lithium-ion trajectory (i.e., redox flow, lithium–sulfur, and sodium-ion)

Constrained circularity



| …Concluding

Findings:

Technological leadership is at the Far East

Technologies grow from 2010

Recent technological diversification

Transition to the “greenest” varieties of batteries, like sodium and iron?