Circular Business Models as Instruments of Corporate Power

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Abstract

The creation of circular business models to deliver the circular economy has been widely accepted as offering significant sustainability benefits. A related expectation is that in creating circular business models, focal companies will necessarily need to encompass multiple stakeholder partnerships to access the resources and skills which they lack. In combination, these two expectations result in a neglect of the potential for focal companies to increase their power and control over the entire product lifecycle for which the outcomes are at best uncertain. This paper proposes a research agenda on corporate power in the circular economy, with a focus on the exclusive control over natural capital that circularity may enable in the form of circular vertical integration. Competitive forces are argued to be fundamental to the corporate drive to control natural capital. The paper is empirically grounded in a case study of VW Group in the automotive industry and its transition to battery electric vehicles. It is concluded that previous research into business model innovation for the circular economy has often mistakenly assumed benign stewardship in which corporate hegemony is mitigated by stakeholder engagement, such that a more critical perspective is needed.

Keywords

Circular vertical integration; circular economy; battery electric vehicles; materials scarcity; recycling.

Introduction

> "The task for our organization is to really try to keep hold of the batteries, and probably get into a second or third lease cycle for the car and then reuse the batteries." Herbert Diess, Chairman of the Board of Management of Volkswagen AG (Quoted in Vellequette, 2021).

The circular economy is held to offer solutions to the resource constraints facing contemporary humanity, reducing both pollution (waste) and resource consumption (new raw materials). Popularised by the Ellen MacArthur Foundation, there is widespread international institutional support by entities such as the UN and EU, and by multiple governments at national level, as well as from NGOs, industry associations and individual companies, with a growing body of academic research into the benefits of the circular economy (CE) and the means to achieve this circularity. The EU (2022) offers two elements to the definition:

> “The circular economy is a model of production and consumption, which involves sharing, leasing, reusing, repairing, refurbishing and recycling existing materials and products as long as possible. In this way, the life cycle of products is extended.
>
> In practice, it implies reducing waste to a minimum. When a product reaches the end of its life, its materials are kept within the economy wherever possible. These can be productively used again and again, thereby creating further value.”

Concepts such as product stewardship suggest a benign corporate contribution, and in any case the circular economy is presented as achievable only through multiple partnerships. Bressanelli et al. (2018: 7395) argue that:

> “…a great degree of vertical integration by one actor in the supply chain is not a necessary condition for Circular Economy implementation.”

Business model innovation (BMI) is often seen as a mechanism to build business ecosystem concepts and partnerships to deliver the CE. Jørgensen and Pedersen (2018:18) in their RESTART concept explicitly link BMI for the CE with ‘alliances and collaboration rather than single companies competing in isolation’. They expand on this later, saying:

> “No single organization can solve the big problems alone. Collaboration is therefore important for companies that want to develop sustainable and profitable solutions, and it is becoming more widespread, both within and across markets and sectors.” Jørgensen and Pedersen (2018: 121)

Similarly, Jonker and Faber (2021:83) claim:

> "So a circular business model is essentially a description of the way in which value creation and retention are organized among parties—at a given moment, in a given context, and given the available resources."

Patala et al., (2022) extend collaborative structures even further with their concept of polycentric governance to include business, the public sector and societal actors instigating new forms of collective action. With focal companies, Jørgensen and Pedersen (2018:112-113) still argue corporate control of the product lifecycle may be possible, and see this control as beneficial to the companies that can do it, and unproblematic to society at large (see also Bocken and Ritala, 2021).

Is it possible that a single company can control the entire product-material circle from original production to in-use life, re-use or second life, eventual recycling, and then back into a new version of the same product? If so, when is this strategy applied, under what circumstances, how will this control be achieved and with what consequences? In parallel with the institutionalisation of the CE there is an emergent critique that identifies the CE with an ideological position informed primarily by technological and neo-classical economic perspectives. Corvellec et al. (2021:8) argue that there is a 'need for questioning how the circular economy is currently conceived, consented, and implemented'. Less consideration has been given to how the circular economy relates specifically to corporate hegemony.

This paper explores the above questions through examination of battery electric vehicles (BEVs) in VW Group, one of the largest producers of passenger cars in the world, that includes multiple brands (including VW, SEAT, Porsche, and Audi) and a network of relationships and alliances with other vehicle manufacturers. Rajaeifar et al. (2022) echo the requirement for partnership when considering recycling BEV battery packs, arguing that there is a need for collaboration between academia, vehicle manufactures, the battery supply chain, and the battery recycling industry to ensure the safe, efficient and economic treatment of such packs.

However, as indicated by the quote at the start of this paper, there is a prima facie case for investigating more closely the 'control' and exclusivity strategy being suggested by senior managers at VW Group. VW Group is not alone in this control strategy, there are niche examples in mobile telephones (Hansen and Revellio, 2020), but is unusual for a major vehicle manufacturer given the scale of resources required by the strategy and the length of time needed to complete the circle (Wells, forthcoming). Battery packs have potential for other less demanding applications once their 'useful' life in cars is over, and therefore could be in use for up to 25 years.

The paper proceeds in the following manner. First, we present a critical review of contemporary treatments of the circular economy and circular business models. While not denying the significance of the circular economy, or of identifying how companies might undertake business model innovation to fit the circular economy, our stance is informed by the need to be sensitive to potentially problematic outcomes. We define CVI as the single corporate integration of the entire product lifecycle, from raw material extraction through to manufacture, the in-use phase, and eventual recycling. We include support services for the in-use phase such as finance and insurance, service and maintenance, etc. because this phase necessarily joins production to recycling. It is recognised that CVI may be partial or incomplete, and subject to shifts in corporate strategy. We also define CVI as achieved through the integration of digital and engineering platforms. We focus on circularity and lithium-ion batteries quite quickly, because in our view circularity is heavily contextual: depending upon the specifics of materials, technologies, products, time, and place (as illustrated by Gülserliler et al., (2022) and van Loon et al., (2022) for the case of washing machines). Techno-economic modelling of car battery recycling demonstrates that profitability is conditional upon a wide range of factors including battery chemistry, transportation, disassembly method, and recycling method (Lander et al., 2021). After a short account of our abductive methodology, we describe our case using a range of secondary sources mostly derived from the specialist industry press and from VW Group. The final section offers analysis, conclusions, limitations, and the scope for further research.

The circular economy and circular business models

There is a large literature on business model innovation, a portion of which is directed to the realisation of a circular economy (Bocken et al., 2021). The literature has a focus on the identification of tools, techniques, business models, and strategies that are useful in creating and deploying BMI for the circular economy (Yang et al., 2017; Lüdeke-Freund et al., 2019). Case studies frequently seek to provide qualitative and quantitative assessments of the extent to which BMI for the CE is more sustainable, typically in a comparative sense against that which has gone before. A second stream of research notes the promotion of circular economy goals via policy support and regulatory intervention (e.g., by the EU: The Directive 2008/98/EC Waste Framework Directive) sets out basic recycling requirements. More recently, the green and circular economy has been defined by the European Commission in an action plan (European Commission, 2020). It is recognised at the policy level that the scope for a 100% circular economy is limited (EEA, 2021), but equally that current performance could be greatly improved (Circle Economy, 2022) and that car batteries remain an area of significant concern (Halleux, 2021).

There is an emergent academic recognition that BMI for the CE has failed to deliver significant and enduring change. Jaeger-Erben et al., (2021) identify the wider institutional context as key to limiting BMI. Bocken et al., (2022) extend this insight into a typology of unsustainable business model archetypes that are antithetical to the realisation of the CE. However, to date the literature has not explored how BMI may indeed align with the CE concept, and yet deepen unsustainabilities. In particular, the exclusionary nature of digital platform business models creates oligopolies that may deepen unsustainability concerns.

These discourses identify the significance of what happens to products beyond the factory gate. What was traditionally regarded as an unimportant ‘aftermarket’ (at least past the first owner) in the automotive and other industries takes on a different meaning when products emerge essentially unfinished in their ability to generate revenue streams while simultaneously extending the reach of corporate power and control (Warren and Gibson, 2021). The analysis from Warren and Gibson (2021) directs attention to the question of the conditions in which circular vertical integration (CVI) may be preferable, or whether the CE is best achieved via the market, or via the ‘networks’ or ‘ecosystems’ identified in the literature. These three alternatives may be regarded as an idealised continuum of possible outcomes. Table 1 identifies potential contextual conditions that in principle might shape the decision to adopt CVI, and whether those conditions might apply to the automotive industry. Historically, the treatment of end-of-life vehicles has been left to the market by vehicle manufacturers, working within regulatory frameworks that stipulate recycling targets. The circular economy and circular business model literature, as noted above, tends to assume that alliances and networks orchestrated by focal firms are the best way to achieve circularity. The option of CVI is given only cursory consideration.

Table 1 Contextual conditions to frame CVI in the automotive industry

Condition	Possible relationship to CVI to achieve the CE	Automotive industry
Velocity of circulation of the product	Higher velocity means more likely for CVI (e.g., aluminium drinks cans)	Slow velocity of circulation. Average car longevity 11-15 years.
Consumer or capital good	Capital goods less likely for CVI due to longevity in use and retrofitting potential (e.g., ships)	Cars, mostly consumer goods. Trucks and buses are capital goods
Material stocks (natural resource availability)	Low stocks relative to anticipated production need means more likely for CVI	Serious shortages of key materials for BEVs
Material value (value per weight scrap versus new)	High material scrap value means more likely for CVI (e.g., aluminium).	High material scrap value but difficult to extract in recycling processes
Product value	High value product may extend product lifecycles and make it more difficult to achieve CVI	High value product, frequently re-sold
Velocity of innovation	High rate of innovation makes it more difficult to achieve CVI	High velocity of innovation in BEV technologies
Production-consumption geography	Consumption in proximity to production means more likely for CVI	Production distant from consumption. Centralised manufacturing, dispersed markets
Technical complexity and risk	Complex or potentially dangerous products means more likely for CVI	Used battery packs are hazardous. Complex products.
Potential for repurposing or second life	Make it more difficult to achieve CVI	Significant potential for second life, but of uncertain scale relative to supply of used batteries.

If the focus is on material scarcity alone, then the logic of circular business models is stronger:

> "Circular business models are particularly well suited to solve challenges related to product life cycles and resource scarcity more broadly." (Jørgensen and Pedersen (2018: 113)

The problem facing VW Group and other major vehicle manufacturers is uncertainty over future demand and supply for key materials in the context of rapid technological change and market growth, which results in a strategic concern to secure and stabilise future supply. Vehicle manufacturers that had already suffered supply shortages of battery packs and key materials in 2019 and early 2020 included Jaguar Land Rover (iPACE), Audi (e-tron), Kia (Niro), and Hyundai (ioniq), while battery suppliers themselves suffered shortages of cobalt, zinc and copper (Evarts, 2019). Battery assembly capacity is usually measured in terms of the annual GWh of cell storage a facility can produce. T&E (2019) estimate that by 2023 there will be at least 16 large-scale battery factories, with a combined capacity of 131GWh in the EU. By 2030 there could be more than 1,000GWh of capacity in the EU (including the UK).

Table 1 also suggests, however, that the car as a product is not ideally suited to adopting CVI as a solution to the material issues, and a battery electric car is even less so given the scope for second life applications. Given the difficulty, it can only be assumed that concerns over the supply of materials has been great enough to compel the attempt at CVI. Extension of the useful life of products is often identified as useful in terms of sustainability, but in the context of virgin material scarcity it becomes a strategic risk unless direct ownership or control over the product when in use is maintained. A related concern is in the market execution of BEVs, by VW Group and others, that currently prioritises large, high-value SUV-style vehicle designs that require large battery packs and associated drivetrain components – comprising up to 50% of total vehicle weight.

Hence, we may expect backward vertical integration into the battery supply chain for key materials and components as capacity is constrained relative to demand. To achieve circularity, however, vehicle manufacturers may need BMI to achieve direct control over the product lifecycle to generate long-term earnings streams (and hence enable the repayment of capital tied up in vehicles in use) and to guarantee the supply of used batteries into the production system. Section three outlines multiple concerns and uncertainties for battery pack reuse and recycling. Hence, CVI may be adopted to reduce some elements of the unknown faced by vehicle manufacturers.

The Circular Economy and Lithium-Ion Batteries

Battery electric vehicles (BEVs) have rapidly become the dominant substitute for petrol and diesel cars, offering both zero toxic exhaust emissions in use and lower carbon emissions per distance travelled or on a total life cycle analysis basis, no matter what the generating source of electricity. A combination of increasingly stringent regulations, punitive taxation and forthcoming outright bans on combustion engines has resulted in a surge in investment in production of BEVs and the required batteries. The result is a burgeoning appetite in the automotive industry for key materials such as cobalt, lithium, and nickel (Bradley, 2021; (Harper, 2021; Poliscanova, 2022) used in the battery packs, and rare earths used in permanent magnet motors. The International Energy Agency (IEA, 2022) has estimated that meeting global pledged emissions scenarios will need 50 more lithium mines, 60 more nickel mines and 17 more cobalt mines by 2030 on the assumption that demand for BEV battery packs will grow from 340 GWh (2022) to 3,500 GWh (2030). Given the anticipated growth in production and the relative scarcity or geopolitical vulnerability of the materials, BEV battery packs are prime candidates for recycling, but future prospects are highly uncertain (Rajaeifar et al., 2022).

The circularity of BEVs is complicated by the potential for the vehicles and the battery packs to follow different pathways. Battery packs and vehicles may be recycled separately, particularly since the battery pack has useful storage capacity even though it may be deemed no longer suitable for use in a car. There are safety concerns with this 'second life' use of battery packs of unknown provenance and history (Christensen et.al. 2021) and multiple legal and regulatory concerns (Ahuja et.al. 2021). Similarly, there are several recycling pathways yielding different costs and benefits.

Second life

Battery packs removed from cars may be viable for other applications, and this may be preferable to immediate recycling. Three broad options with end-of-life battery packs are possible: re-use in whole or in part in another vehicle; re-use in whole or in part in a less demanding application; or recycling.

Re-use in existing or new vehicles is not currently practiced, although it may be in the future. Concerns over reliability (and hence warranty and reputational risks) are probably too great. Therefore, the primary focus for second life applications is with non-vehicle uses in static energy storage. Applications include charging stations for BEVs, storage for renewable energy sources, load balancing on electricity grids, mobile network back-up systems, and emergency power provision in safety critical applications such as hospitals.

VW Group companies have conducted trials with e.g., the use of second life battery packs at dealerships to store electricity from rooftop photovoltaic systems and then deploy it in fast-charge stations at the dealership (Randall, 2021)

Battery pack recycling

There are several methods for recycling lithium-ion Batteries from electric vehicles (Harper, 2019). Early approaches to recycling focused on pyrometallurgy, where batteries are smelted to recover the most valuable materials like nickel and cobalt. Although crude, this method uses existing infrastructure established to recover materials from waste electrical and electronic products. Smelting can process an enormous variety of battery wastes but results in low rates of material recovery, while battery components used to fuel the process end up as slag.

Currently, the dominant approach is to shred batteries, separate materials, and then apply hydrometallurgical techniques. This results in higher rates of materials recovery (Harper, 2019). However, because the products of shredding are mixed, the chemistries required to selectively remove certain materials are more complicated. This has led many to question whether shredding as a preliminary cell-breaking step is the most appropriate (Thompson, 2021). Whilst mechanically simple, it results in greater chemical complexity downstream.

An alternative approach would be to disassemble cells, and cleanly remove the materials from electrode foils (Lei et.al. 2021). This could lead to much greater simplicity in the chemical steps that follow, thus trading decreased chemical complexity with greater initial mechanical complexity (Thompson et.al. 2021). Crucially, 'design for recycle' battery packs engineered for easy disassembly would significantly aid the process (Thompson et.al. 2020). As noted in the case study, VW has standardised the design of battery packs as an aid to disassembly automation, thereby improving material yield and economic viability in recycling.

One of the significant concerns as the industry scales, is the significant risks associated with handling batteries towards the end of their lifecycle, where their condition is uncertain (Christensen, 2021).

Automated approaches could be leveraged for end-of-life gateway testing and triage (Rastegarpanah, 2020) and pack and cell disassembly (Glöser-Chahoud et.al. 2021).

Another approach under development is so-called 'direct recycling' (Gaines et.al.2021). Here, rather than taking the battery materials back to an earlier, more basic state to feedback earlier in the battery supply chain, the value inherent in the structure of the material is retained, and the material is reprocessed or 'healed'. This technology offers the potential of retaining the embodied energy and carbon that has gone into materials' manufacture. Such a concept would resonate with the closed battery ecosystems being pioneered by firms like NIO with its battery swap system. Furthermore, such approaches have been applied where batteries have been recalled because of defects, but where battery material is in relatively good condition due to short service life (Sloop et.al. 2020). Again, with VW Group having direct control over the battery pack during its lifecycle it may be viable to apply this technique.

Batteries and circularity: technical and economic considerations

The most important feature of planning for the future treatment of end-of-life battery pack is uncertainty. Forecasting the rate of return and the optimum pathway for battery packs is extremely difficult. Table 2 summarises the main concerns. Note most of the developments noted are intended to reduce material and / or manufacturing costs, so as to reduce the price paid by consumers or the finance costs to them. Battery longevity is an exception but note that this would improve residual values, a key issue given the significance of depreciation in the total cost of ownership.

Table 2 Technical and economic issues for automotive battery pack recycling

Issue	Developments	Implications
Battery chemistry changes (Next generation technologies).	Investigations into alternative materials for batteries, and into solid state batteries.	Reduction in high-cost materials (e.g., Cobalt) reduces the metals value of scrap batteries.
Battery chemistry changes (Lithium Ferrophosphate or LFP).	Use LFP batteries in less demanding applications.	Eases critical materials concerns. Cell to pack enables acceptable volumetric and gravimetric energy density. But less value to recycle. Lower scrap value reduces the viable distance for transportation or viability of recycling processes
Battery longevity	Very long life batteries	Could outlast the vehicle and still find second use applications.

Battery construction changes	Modular design battery packs to enable cells or modules to be replaced	Enhance the working life of the battery in first use or second use applications. Allows viable cells or modules to be reused when the remainder of the pack is scrapped. Makes disassembly easier
	Battery swap architectures e.g., NIO NS8, CATL EVOGO	Battery ownership remains with battery provider which could aid utilisation intensity and enable business models for a circular economy.
	Sealed battery packs	Reduces scope for repair of battery packs; increases cost of recycling
	Cell to Pack	Could reduce the complexity of vehicle battery packs to aid easy serviceability / recyclability, whilst still enabling packs to be removed easily.
	Cell to Platform	Making the vehicles the structural housing for cells saves weight and cost, but could be problematic for recycling / serviceability.
Battery form factor and vehicle size	Development of smaller vehicles with smaller battery packs	Reduced potential for second-life applications
Battery pack recycling techniques	Disassembly or hydrometallurgy pyrometallurgy	Significant differences in the quality of recovered materials (purity) and the cost of recovery. Design for recycling is a highly important for disassembly.
Growth in second life applications	Stationary storage; back-up power; etc.	Issues over warranty; uncertainty over rate of return of used batteries
Electricity generation	Growth in renewable sources of electricity	Increases demand for second-life applications, but may also increase demand for new battery packs designed for that purpose

Traditionally, vehicle manufacturers have been distant from car recycling, other than seeking to ensure (in the EU at least) that the cars are technically able to meet the criteria for recyclability (95% from 2015 onward). Techno-economic studies of car recycling before the advent of battery electric vehicles revealed a time/cost trade-off with the removal of non-metallic components.

One solution that has been proposed to solve many resource management challenges around lithium-ion batteries is ‘digitalisation’ (Reed et.al., 2020). Digitalisation assists the introduction of ‘battery passports’ as mandated in the European Battery Regulations (Melin, 2021). Such an approach could enable crucial data that could be used at the end-of-life to help characterise and process the battery, along with data about the initial specifications of the battery, verification of authenticity, ESG credentials of the constituent critical materials, and even live data about the battery condition.

Blockchain technologies have been proposed as one method for the management and verification of materials in a circular economy of lithium-ion batteries (Cheng, 2021; Hristova, 2021). By keeping data in a decentralised distributed ledger, the robustness and authenticity of data can be verified across a broad range of sources and there is no single point of truth or failure. Blockchain technologies could be used to verify the ESG credentials of the materials contained within lithium-ion batteries. With advanced battery management systems, there is potential to keep service records of batteries in use. This could help with value characterisation when the battery reaches the end of its first life.

The above discussions gave a brief insight into some of the multiple, and often contradictory, considerations vehicle manufacturers must have regarding battery pack recycling. Such volatile and uncertain conditions may stimulate vehicle manufacturers to impose hierarchal solutions, but those solutions depend upon controlling the whole product lifecycle. The following section explains how we sought to understand this issue in the case of VW Group.

Methodology

The conceptual approach and the empirical analysis adopted for this paper embraces an abductive reasoning perspective (Bell et al., 2018). The initial instigation comes from grounded expertise in the automotive realm and an understanding of contemporary academic debate over the circular economy. In combination, these two elements sparked the quest for deeper investigation following news that VW Group had established a battery recycling plant. This prompted a search of multiple sources, including the specialist automotive news media and scientific publications to refine and align our understanding of circular economy strategies. Hence, we deductively established our initial understanding of circular economy strategies from the literature, but then refined this understanding inductively based on our unfolding evidence of the VW Group. This process was conducted iteratively to allow convergence between our theoretical framing and the empirical analysis. In consequence, the concept of CVI was established, and the potential components of CVI listed in Table xx were identified empirically. Thereafter, the significance of service support activities became evident and added to the CVI concept.

VW Group was not, therefore, selected as an illustrative or representative case, so much as potentially an extreme outlier qualitative case study (Yin, 2016) of a range of strategic possibilities, although VW Group is one of the largest vehicle manufacturers in the world. The embrace of CVI by VW Group can be perceived as a means of enacting the transition from product manufacturer to supplier of mobility as a service.

There are caveats with the use of secondary data in constructing this case study. Only that information which is publicly available can be used, and this information may mis-represent or otherwise distort the objective reality of VW Group. Further, information may be released by VW

Group with the express purpose of shaping public opinion and debate. Without a comprehensive survey of the entire industry, it is not possible to offer a definitive conclusion on the theoretical veracity of the circular vertical integration concept, or its application beyond the realm of the automotive industry. It can be observed anecdotally that other major vehicle manufacturers are taking similar steps (Martinez, 2022), while others are taking the 'alliance' and partnership route including the use of independent recyclers such as Umicore and Redwood Materials (Randall, 2022a; 2022b; 2022c).

The search method involved using related search terms such as 'VW + battery second life' and 'VW + recycling' and 'VW + marketing electric cars' to search the key sources (InsideEVs; Green Car Congress; Energy Storage Publishing; Automotive News; Electrive) supplemented by more general sources including Reuters and VW Group press releases and corporate information. The search was extended backwards to 2015, when the diesel scandal first emerged in the US.

VW Group case study

VW Group may not rely entirely on CVI throughout the product lifecycle. In many of the items listed in Table 3, the key aspect is that VW Group is extending direct control, often incrementally. For example, few if any VW Group BEVs are, as of 2022, on a second or third lease cycle. VW Group in 2021 established strategic partnerships with Umicore and 24M as well as a long-term supply agreement with Vulcan Energy Resources (lithium supplier). The battery recycling facility in Salzgitter was started only as a pilot plant in 2021.

Table 3 Putting CVI into action: the VW Group case

Item	VW Group case	Comment
Battery materials production	PowerCo.	Part of the US$20B investment noted below.[1]
Battery components production	PowerCo	Part of the US$20B investment noted below
Battery pack design	PowerCo. Salzgitter Center of Excellence	Standardised design launched in 2021, to be used in 80% of VW Group vehicles[23]
Software design	Cariad.	Significant delays in software delivery for VW Group

[1] https://newspressuk.com/publicReleaseView/100729/56493
[2] The battery system of the ID. models is made up of aluminium profiles and has a scalable design. Each compartment holds a battery module comprising 24 cells with a flexible outer shell. The 45 kWh battery contains seven modules, the 52 kWh battery eight modules and the 58 kWh battery nine modules; these are located in ten compartments in each case. The 77 kWh battery is made up of twelve modules filling all twelve compartments. See https://newspressuk.com/publicReleaseView/97642/53924/V2VsbHNwZUBDYXJkaWZmLmFjLnVrRW1haWxIYXNo?token=AGMp3dIoOPQCYlvOEENJ
[3] https://www.electrive.com/2021/03/22/vw-brand-joins-audi-in-ending-combustion-engine-development/

		vehicles. Expected to employ 10,000 staff by 2025.[4]
Battery pack assembly	PowerCo. Braunschweig and other locations	VW Group looking for an IPO. US$20B to be invested in the battery business for 5 plants by 2030. Salzgitter will have capacity for 40 gigawatt-hours of cells, for 500,000 cars p.a.[5]
	20% share of Northvolt	Second investment, of US$620 million in 2021.
Electric motor production	Audi, Gyor factory in Hungary	Investment of US$320.2 million. Increase in-house production from 30% (2022) to 60% (2030).[6]
Vehicle assembly	VW Group	Transition to BEV manufacturing in most major markets
Outbound logistics	VW Group Services GmbH	Outbound finished vehicle logistics. Also components transport and warehousing. Pre-dates BEV strategy
Agency model dealerships	First applied to German franchised dealers selected to sell the BEV models.	Gives greater control over inventory, pricing, etc[7].
Extended warranties	ID-3 and ID-4	8 years or 100,000 miles
F&I subsidiaries	VW Financial Services. "Lease&Care" packages.	Offer modular full-service leasing for ID models[8]. Offer leases for used BEV models[9].
Mobility as a Service	MOIA	Ridesharing and ride pooling service (see https://www.moia.io/en)
Wall-mounted charge points	Elli. Available also outside VW Group	White label charge points. 3 variants up to 11kW.[10]
Charge point public networks	Ionity. Joint venture with multiple partners	Pan-European high-speed charging network.
	Elli. Ultimate aim to provide a 'comprehensive energy ecosystem' including e.g., V2G[11]	The subscription includes 330,000 charge points throughout Europe, including 10,000 fast chargers at over 3,000 locations

[4] https://www.autocar.co.uk/car-news/new-cars/volkswagen-project-trinity-previewed-next-electric-flagship
[5] https://europe.autonews.com/automakers/vws-battery-unit-faces-supply-chain-hurdles-road-ipo
[6] https://europe.autonews.com/automakers/audi-joins-bmw-mercedes-others-bringing-e-motor-production-house
[7] https://www.electrive.com/2021/05/21/vw-to-apply-agency-model-to-group-brands/
[8] https://www.electrive.com/2020/07/22/vw-offers-modular-full-service-leasing-for-the-id-3/
[9] https://europe.autonews.com/automakers/vw-planning-lease-used-evs-strategy-keep-control-batteries
[10] https://www.electrive.com/2022/07/21/europe-elli-now-offers-wall-box-in-three-more-countries/.
[11] https://www.volkswagenag.com/en/news/2021/10/volkswagen-group-drives-forward-intelligent-mobility-solutions.html

Car rental ownership	Europcar	Acquisition via Green Mobility Holding joint venture in 2022.[12]
Second life applications	Power Storage Container (PSC)	Audi Charging Hub in Nuremberg; copied at Zwickauer Tor West. Stationary storage for car charging facilities.[13] See also trials in VW Group[14].
Reverse logistics	VW Group Services GmbH	Likely for battery reverse logistics but not confirmed.
Battery evaluation	BattMan ReLife system.	Rapid state of health analysis. Also used in dealerships. To determine whether to re-use in whole or part, use in a second life application, or recycle.[15]
Battery pack disassembly	VW Group Components, Salzgitter.	3,600 battery systems per year. “As pilot operation commences, the Volkswagen Group takes another committed step towards sustainable end-to-end responsibility for the entire value chain of the electric vehicle battery”.[16]
Battery pack refurbishment and repair	VW Group Components	Currently under trial a Salzgitter. May be rolled out to dealerships in the future.
Battery pack materials recycling	Partner organisations	Re-supply to VW manufacturing.
	Northvolt	4GWh plant in Sweden by 2030[17]

In so far as senior management express corporate direction, the selection of quotes below make intent abundantly clear, even if the eventual execution and realization of this intent is more problematic.

[12] olkswagen-newsroom.com/en/press-releases/green-mobility-holding-continues-progress-with-acquisition-of-europcar-mobility-group-and-welcomes-extension-to-facilitate-completion-7765

[13] https://www.electrive.com/2022/07/15/vw-launches-hpc-park-with-2nd-life-batteries-in-zwickau/

[14] https://www.volkswagenag.com/en/news/2021/05/second-life-cycle-for-batteries-reduces-their-carbon-footprint.html

[15] Re-use, second life or recycling? Volkswagen BattMan ReLife knows - electrive.com

[16] https://newspressuk.com/publicReleaseView/96243/52690/V2VsbHNwZUBDYXJkaWZmLmFjLnVrRW1haWxIYXNo?token=Hjs6TTjacatIxoMOr59V

[17] https://www.electrive.com/2021/06/09/volkswagen-invests-another-e500mn-in-northvolt/

> “Volkswagen intends to keep control of the raw material cycle for batteries at all stages. The battery and its raw materials form the foundation for the recycling economy of future mobility”. Herbert Diess, Chairman of the Board of Management of Volkswagen AG in VWGC (2021).

> "In Europe, we are trying to get a second lease and even a third lease, and keep the car in our hands…Battery life, we think today is about 1,000 charging cycles and around 350,000 kilometers [about 215,000 miles], something like that. So, the battery would probably live longer than the car, and we want to get hold of the battery. We don't want to give the battery away." Herbert Diess, Chairman of the Board of Management of Volkswagen AG in VWGC (2021).

> “We are starting from the beginning to cover all aspects, from the mine to the end product…We need to understand the sourcing, pricing to have a competitive product.” Kai Alexander Mueller, Chief Financial Officer, PowerCo. [18]

> "Vertical integration is the key to this… A third of the cost of the battery is manufacturing, engineering and integration into the vehicle. Two-thirds are the components, the raw materials and raw materials processing…” Joerg Teichmann, VW Group Chief Procurement Officer[19].

> "We are looking at the entire process chain from the mine to recycling. We have to get actively involved in the raw materials business." Thomas Schmall, VW CEO of Volkswagen Group Components[20].

> “We assume that around 80 per cent of Volkswagen Group electric vehicles are leased or financed through us…We are deliberately focusing on the advantages of leasing for electric mobility. With leasing, our customers do not have to worry about the subsequent marketing or value of their vehicle after the contract period.” Jens Legenbauer, Spokesperson of the Board of Management of Volkswagen Leasing GmbH[21].

In terms of the major lifecycle stages, VW has an unusually high level of vertical integration in the component supply and manufacturing stages for its electric models. This is business model innovation to put in place the structures for CVI. Volkswagen Group Components contributes 40% by value of the parts for the ID-3 and ID-4 models, up by 10 percentage points compared to the equivalent petrol or diesel cars (Randall, 2020). In the use phase, VW has also used the introduction of BEVs to move its dealerships in Europe to an ‘agency’ model, allowing a much higher degree of

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[18] https://europe.autonews.com/automakers/vws-battery-unit-faces-supply-chain-hurdles-road-ipo
[19] https://europe.autonews.com/automakers/vw-stellantis-renault-enter-new-battlefields-ev-race
[20] https://europe.autonews.com/automakers/vw-stellantis-renault-enter-new-battlefields-ev-race
[21] https://www.electrive.com/2020/07/22/vw-offers-modular-full-service-leasing-for-the-id-3/

control over key issues such as discounting, increased the share of total business captured by the in-house finance and insurance businesses, and introduced multiple leases over the lifetime of the models. In the re-use phase VW has invested in analysis and dismantling operations, again unlike the traditional practice with petrol or diesel cars, but does use partners to process the recovered materials to re-supply the battery manufacturing plants.

VW has distilled all the above, and presented the public with a ‘big picture’ that highlights four key technology platforms that underpins their ‘NEW AUTO Strategy’ transition (Volkswagen AG, 2022a):

- Mechatronics. From 2026, VW will bundle its future technologies on the Scalable Systems Platform (SSP), the next generation of all-electric, fully-digital and highly-scalable mechatronics platform (VWAG, 2022b). More simply put, a universal BEV product architecture. VW aspires to eventually build models for all its brands and segments on the SSP, more than 40 million Group cars throughout its life cycle.

- Battery and Charging. The biggest single cost in electric cars is the battery. Range and charging speeds are vital ancillary considerations for the market success BEV models. Therefore, from 2023, VW’s single ‘unified cell’ – rather than several different ones – will be used in up to 80% of the Group’s models (Ruffo, 2021). VW intends to leverage economies of scale and scope to reduce costs, thus making the battery its ‘core business’ by taking control of the entire battery value creation process.

- Software. VW estimates that by 2030, 30 percent of global mobility market revenue will come from software-based services, on par with BEV and ICE sales. VW’s own software and technology company CARIAD will develop the new E3 2.0 software platform for all Group vehicles and thus exploit synergy effects across all the brands (CARIAD, 2021). VW’s software platform is intended to form the technical foundation for data-based business models, new mobility services and autonomous driving for the Group and its brands. The group has struggled to deliver all the required functionality (Randall, 2022d).

- Mobility Solutions. VW expects fully autonomous ‘Mobility and Transport as a Service’ to be an integral component of its NEW AUTO strategy. By 2030, VW (in collaboration with ARGO AI) hoped to offer integrated mobility and transportation solutions that covers all customers’ needs on a central platform. ARGO AI however went bankrupt. VW sees its mobility solutions platform as being comprised of four stacked levels: the driverless system, its integration into vehicles, fleet management, and a digital mobility platform for customers.

Analysis and conclusions

The paper shows that VW Group has attempted to put in place the structures, business model and technologies to achieve what we define as ‘circular vertical integration’ (CVI) of electric car batteries, thereby controlling scarce and valuable resources for years ahead. The strategy includes the facilities to source materials and build their own battery packs and in parallel the facilities to dismantle and recycle them. In addition, VW Group is seeking greater control over the purchase and use of battery electric vehicles (BEVs) through the adoption of features such as an ‘agency’ sales model for dealerships, extended warranties on batteries, multiple lease periods per car, integration of finance and insurance services, and ventures into ‘mobility as a service’ offerings. In the longer term the strategy hinges on a transition towards the provision of (digitally-integrated) mobility services.

The paper thereby extends the critique of the circular economy and circular business models by highlighting the potential for corporate monopolisation of key resources. The paper also extends the critique on the negative aspects of BEVs, where previous studies have highlighted for example mobility injustice (Henderson, 2020), the assumed economic rationality of consumers (Bergman et al., 2017), energy injustice (Sovacool et al., 2019), and the ways in which the achievement of zero carbon emissions in the developed West has negative repercussions in Africa (Sovacool et al., 2020). The socio-economic costs of cobalt mining (Sovacool, 2019) constitute a significant motivation for recycling, but the implications for corporate control have not been examined. In effect, there is a cascade of solution-problems here. BEVs are a solution to carbon emissions and pollution, but have negative consequences in mining for ores. Resolving some of those consequences with a circular economy business model raises new concerns over corporate control over scarce resources.

Hence, we can identify four broad conclusions for sustainability concerns arising out of CVI for the CE. First, the BMI steps described above are crucial to allowing VW Group to ‘close the circle’ and thereby manage the issues identified in Tables 1 and 2. The replacement of the existing global fleet of petrol and diesel cars constitutes a vast market opportunity, while extension into lifecycle management offers the prospect of capturing a greater share of the revenues generated by cars in use.

Second, CVI in combination with electrification enables claims to be made regarding the climate emergency, while offering no substantive challenge to mass personal mobility with different but nonetheless enormous sustainability burdens. In this sense, CVI and the CE offers new opportunities for corporate greenwashing.

Third, the business model potentially allows VW more scope to determine the ‘velocity of circulation’ of materials in the circular economy, another neglected feature. That is, VW might in the future be in a position to determine whether its best interests lie in retaining the stock of materials in use (i.e., as battery packs still on vehicles), or as stored materials following dismantling and recycling, or used again in the construction of new batteries and materials. This strategy therefore offers VW the potential of maximizing lifecycle profitability, and reducing the risks of supply uncertainty, but the outcomes may not be socially or even environmentally optimum.

Fourth, CVI also enhances control over consumers and the value of the data generated by vehicles in use. This enhanced control and data availability particularly applies to those second or third use consumers that hitherto have been largely unknown to vehicle manufacturers.

VW’s adoption of CVI seemingly reverses course on the organization principles of the automotive industry’s previous efforts at a circular economy by changing how competition and innovation will happen in the future. The CVI is reminiscent of times past by steering the industrial organization of supply chains towards competition between vertically integrated firms with closed systems and away from competition between coalitions of firms specializing in compatible components and systems (Gawer and Phillips, 2013). By leaning into hierarchal controls, supply chain authority, OEM-supplier contracts, and quasi-captive systems, VW’s platform moves away from the idealistic circular economy ecosystem that runs on distributed decision-making processes, where members retain residual control and claim over assets.

VW’s CVI strategy resembles more of a power hub supply network, where prices, quantity and standards are unilaterally set (Jacobides et al., 2018), and combined with the network effects associated with digital platforms, it is reasonable to argue that the CVI business model will incentivise oligopolistic behaviour in a similar manner. Caution is indeed warranted if VW's approach is indicative of how vehicle manufacturers or other companies intend to conduct business in the future.

There are limitations to this single case study, grounded in the specific context of the automotive industry. The case is not necessarily representative of the industry as a whole, where divergent approaches are evident. Neither is the case representative of other product-service realms. However, we consider that the case does illustrate that the concrete manifestation of the CE and BMI is subject to a range of contingent conditions, which can be elaborated and tested in further, more generalised research.

In particular, future research could consider how far competition for resources, either absolute or via geo-political tensions, could create the context for greater CVI. It would also be worthwhile to consider the opportunity costs of CVI at a societal level. There may be other, more beneficial, applications for these scarce resources that are blocked because they are controlled inside corporate circular economy loops.

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