中国新能源汽车产业的创新发展模式与未来方向

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摘 要：新能源汽车是我国现代化产业体系的重要组成部分，近年来凭借其在技术创新、产业规模和绿色低碳等领域的优势快速崛起，成为引领现代产业发展的重要力量。作为战略性新兴产业之一，新能源汽车是关键核心技术研发与突破的先锋产业，是工业集聚与产业链高度协同的中心产业，也是价值链延伸领域广阔的未来产业。新能源汽车是新时期中国制造走向世界的名片，要保持领先优势，加紧关键核心技术突破，实现产业链自主可控。面向未来，需优化数据驱动的“人—车—路—云”协同系统，在开放合作中适应环境新变化，市场新需求，引领现代产业体系的构建与演化。

关键词：新能源汽车 战略性新兴产业 产业创新 产业链

JEL 分类号：O14, O33

一、引言

新一轮科技革命和产业变革加速全球产业格局调整，面对世界百年未有之大变局，以创新引领现代化产业体系建设是中国把握新一轮科技革命和产业变革的历史机遇期，发展如数字经济、人工智能、新能源、生物技术等新技术、新产业，同时转型升级劳动或资本密集型传统产业，通过数字化、智能化和绿色化手段提升产业体系整体竞争力和抗风险能力（芮明杰，2018；盛朝迅，2023）的重要举措。战略性新兴产业作为现代化产业体系的重要组成部分，扮演着引领产业前沿与未来经济发展的重要角色。根据国家统计局制定的《工业战略性新兴产业分类目录（2023）》，我国战略性新兴产业包括新一代信息技术、高端装备制造、新材料、生物、新能源汽车、新能源、节能环保、航空航天、海洋装备九大产业[①]。新能源汽车产业作为战略性新兴产业的重要构成之一，与燃油汽车这一传统产业在工业基础和市场等多个方面存在交叉和竞争关系，但又以主导技术的革命性突破在很大程度上改变了传统汽车工业的技术经济属性，成为兼具数字化、智能化、绿色化特征的战略性新兴产业。中国新能源汽车产业的创新发展模式既有技术革命性突破，又有商业模式创新，更是中国配套完备的产业集群和充分市场竞争的结果。

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① 国务院第五次全国经济普查领导小组办公室：《工业战略性新兴产业分类目录（2023）》。

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新能源汽车的技术创新主要体现在电池技术、电控系统和智能网联技术的更迭与突破。新能源汽车推动了汽车产业能源技术革新，降低对化石燃料的依赖，减少尾气排放，带来了显著的环境效益，有助于实现碳达峰和碳中和目标。国内新能源车企与高校及研究机构协作，攻破技术难关，在新能源电池技术等领域屡达技术创新高峰。其中，多个新能源汽车研发与电池技术的项目获得2023年度国家科学技术进步奖二等奖，包括比亚迪股份有限公司牵头完成的《新一代电动汽车关键部件及整车平台自主研发与大规模产业化》，宁德时代牵头与企业和科研机构的合作项目《面向大规模产业化的动力电池研发与制造关键技术》等。

现代化产业体系是创新链—技术链—产业链—价值链—服务链的顺畅衔接，相互支撑（白雪洁等，2022）。依托先发优势与规模优势，创新链与技术链是中国新能源汽车产业异军突起的核心支撑。在产业链和价值链的重构方面，新能源汽车产业链涵盖电池制造、整车生产和充电基础设施等多个环节，联动相关产业的发展，形成新的经济增长点。我国汽车产业链从过去依赖生产发动机、变速箱和车桥等传统零部件，逐步向电池、电机和电控等新能源核心技术部件转型。在传统燃油车时代，中国汽车产业早期采取了以市场换技术的发展策略，一大批国际知名整车和零部件企业进入中国市场，对中国汽车产业集群的形成，对本土汽车企业的技术管理外溢和产业链带动作用不可忽视。但进入智能电动化时代后，传统燃油车的核心零部件被电动汽车的关键部件所取代，国内企业如宁德时代和亿纬锂能等在动力电池领域取得了技术优势。与此同时，智能汽车的软硬件供应商如地平线和禾赛科技也迅速崛起，成为创新链的重要一环。随着电动化和智能化的快速推进，中国汽车供应链的自主性大为增强，形成了面向国内外市场的双循环格局，不仅满足了国内需求，还在全球市场中发挥着越来越重要的作用（李方生等，2021）。传统汽车产业的价值链以制造为中心，随着智能电动汽车时代的到来，服务链成为新的价值高地，包括数字金融保险、电力能源供应、数据服务等新兴服务能力的强弱在很大程度上决定新能源汽车的整体竞争力。

本文在探讨中国新能源汽车发展现状的基础上，分析了新能源汽车产业技术创新的基本逻辑，相比传统燃油车，新能源汽车产业实现的是技术变轨突破与跃迁，电池技术、电控系统和智能网联等技术的集成式创新为汽车产业抢抓新一代技术革命和产业变革机遇期，实现产业升级奠定坚实技术基础，也为新能源汽车产业的集群式创新提供源动力。相比于当前多数关注新能源汽车产业发展的文献，本文的边际贡献在于分析中国新能源汽车产业如何以技术带动产业链整体的协同创新，结合实际案例的阐释增强说服力。

二、中国新能源汽车产业的现状特征

中国新能源汽车产业的起步几乎与国际同步，1999年，国务院多部门联合开展“清洁汽车行

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动”，拉开了中国汽车产业低碳转型的序幕。2008年以前，新能源汽车主要处于概念形成与产业酝酿期。2001年，科技部启动“863”计划“电动汽车重大科技专项”项目，确定了“三纵三横”的电动汽车发展布局，其中“三纵”是混合动力汽车、纯电动汽车、燃料电池汽车三条动力路线，而“三横”则为能源动力总成控制系统、电机及其控制系统和电池及其管理系统，这一时期是新能源汽车技术探索阶段，是产业发展的奠定期。2009年至2014年，中国新能源汽车产业进入战略形成和技术与市场积累阶段，实施新能源汽车战略，推动新能源汽车及关键零部件的产业化，重点是掌握专用发动机和动力模块优化设计技术、规模生产工艺和成本控制技术。2010年，新能源汽车产业被纳入战略性新兴产业范畴，并明确了作为产业共性技术，要突破动力电池、驱动电机和电子控制领域关键核心技术，推进插电式混合动力汽车、纯电动汽车推广应用和产业化。2012年发布的《节能与新能源汽车产业发展规划（2012—2020年）》进一步明确了中国新能源汽车的主要战略方向是纯电动汽车。

随着产业的数智化变革和绿色低碳发展方向日益清晰，中国由头部新能源汽车企业开启了独立自主的研发制造活动，形成了产业链协同，纵向发展的内生动力。2021年和2022年中国新能源汽车销量增速分别达157%和96%。至 2023 年，国内新能源汽车在整个汽车市场的占有率超过30%，在大中城市这一占比更高。中国新能源汽车产业的创新发展模式已然形成且在不断地自我完善之中，中国新能源汽车在全球市场中的地位也逐渐提升（李晓华，2024）。

（一）需求市场拉动成为新能源汽车产业创新发展的重要动力

近年来，中国新能源汽车消费规模持续扩大，对燃油车的替代率逐年提升，增长趋势如图1所示。据中国汽车工业协会数据[②]，2023年中国新能源汽车产销量分别达958.7万辆和949.5万辆，同比分别增长35.8%和37.9%。而回观2016年，中国新能源汽车销售规模仅为30万辆，销售市场占有率为1.8%，自2020年起销售量迅速攀升，至2023年销售市场占有率已达31.6%。从新能源汽车的出口来看，2023年中国出口新能源汽车120.3万辆，约占汽车总出口的25%，相比于2022年增加3%。2023年全球电动汽车销量接近1400万辆，其中约60%在中国，25%在欧洲，美国则约为10%，毫无疑问，从消费端来看，中国是全球最大的新能源汽车消费市场。从出口市场来看，中国新能源汽车在新兴和发展中经济体尤受欢迎，2022~2023年，中国新能源汽车占印度尼西亚、泰国和巴西电动汽车销量的40%~75%不等，预计随着更实惠车型的推出，销量还可能进一步增长[③]。据国际能源署（IEA）发布的《全球电动汽车展望2023》预计[④]，至2030年，全球电动汽车的销量将超过

[②] 中国汽车工业协会：http://www.caam.org.cn/tjsj。
[③] IEA (2024): Global EV Outlook 2024, IEA, Paris https://www.iea.org/reports/global-ev-outlook-2024.
[④] IEA (2023) : Global EV Outlook 2023, IEA, Paris https://www.iea.org/reports/global-ev-outlook-2023.

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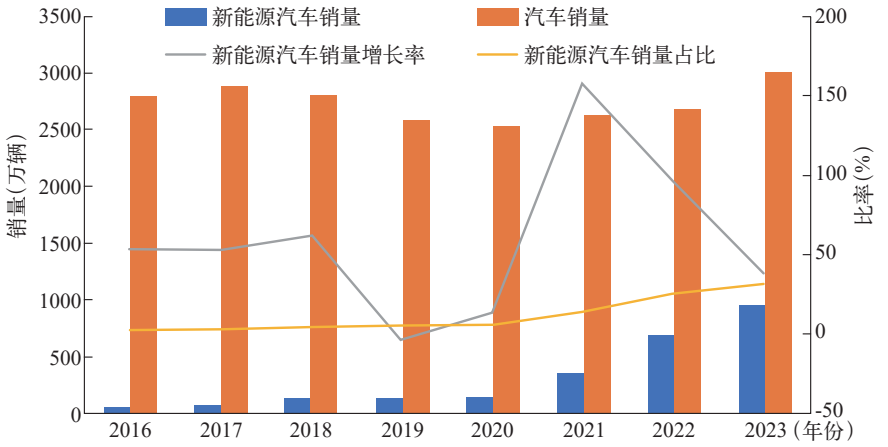

图1：中国新能源汽车销量及其增长与占比情况（2016～2023年）

资料来源：作者据中国汽车工业协会数据绘制。

7000万辆，保有量达到3.8亿辆，年度新车渗透率有望超过60%。这一庞大的现实和潜在需求市场无疑是新能源汽车产业发展的重要拉动力量。

（二）新能源汽车产业链的区域分工和空间格局日渐清晰

从中国新能源汽车产业空间布局来看，总体呈现多点集群与带状分布的态势，主要集中在长三角，珠三角，成渝与京津冀地区。各产业集群内部有着相对完整的供应链体系，呈现由“链式”向“网状”发展态势。长三角地区是中国新能源汽车整车制造的最重要集聚地之一，各地区发挥独特优势，协同发展，形成了新能源汽车“4小时产业圈”：由上海提供芯片、软件等组成汽车“大脑”，江苏提供动力电池，浙江提供一体化压铸机，安徽整车组装，一台新能源汽车的完整产业链构建在4小时车程内。在整车企业分布方面，上海布局了上汽集团和特斯拉，江苏及安徽聚集了蔚来、理想、奇瑞和江淮等企业，浙江有着“吉利系”及零跑等新势力。珠三角经济带也是新能源汽车整车制造的核心区域之一，龙头企业包括比亚迪和广汽集团。其中比亚迪更是囊括整车、动力电池、电机电控、汽车后市场等整条产业链，在全国进行生产布局。新能源汽车的产业链和集群式发展格局在发展初期就已经基本形成，与燃油汽车的产业集群有所关联但又不局限于此。

（三）中国成为全球新能源汽车动力电池的重要来源地

在新能源汽车电池生产方面，中国形成了多个重要的产业集群。据中国汽车动力电池产业创新联盟数据，2023年我国动力电池累计装机量387.7GWh，累计同比增长31.6%，中国企业占世界总装机量约为65%。国内动力电池的头部企业如宁德时代、比亚迪、中创新航、国轩高科等主要分布在东南沿海地区。江苏的苏州和无锡等地，通过引进先进的生产技术和加强研发投入，形成了

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重要的电池生产基地。2023年江苏省动力电池产业产能、产量、销量等多项指标位列全国首位，呈现持续领跑态势[5]。江苏的动力电池产业集群形成“常州、南京两大集聚中心，无锡、南通2个材料装备配套基地，盐城、苏州、镇江等多点支撑”的区域协同发展格局。作为新能源新城，常州在新能源电池生产上表现突出，中创新航、蜂巢能源总部均设于此，据不完全统计，江苏有锂电池产业基地69个，常州锂电池基地就多达19个[6]。

（四）加强基础设施建设完善产业发展环境

充电基础设施作为新能源汽车的配套必需品，在新能源汽车的普及与便利出行方面提供重要支撑。截至2024年5月，中国充电基础设施累计达992.4万台，同比增长56%。中国已建成世界上数量最多、辐射面积最大、服务车辆最全的充电基础设施体系，覆盖全国大中城市和高速公路，未来还将进一步提高充电设施网点密度。此外，换电站作为一种新型便捷的充电模式，也在快速布局建设中。2023年，中国新增换电站1594座，累计建成换电站3567座[7]。蔚来品牌换电站率先布局发展，当前占约65%的份额，截至2024年6月，蔚来在全国已建成换电站超过2400座，提供了更为便捷的供电服务[8]。

三、中国新能源汽车产业的创新发展模式

（一）以自主创新追求关键核心技术自主可控

我国新能源汽车产业本质上由市场主导，关键核心技术的自主创新是其发展的首要特征，约占新能源汽车成本50%的“三电”技术：电池、电机及电控技术在我国从发展初期就选择了自主创新的道路。此外高端零部件设计制造和智能网联技术等领域的自主创新水平也不断提升。根据《新能源汽车产业发展规划（2021—2035年）》，到2025年，中国新能源汽车的动力电池、驱动电机、车载操作系统等核心技术将达到国际领先水平。

1. 动力电池研发与应用

动力电池技术是新能源汽车的核心部件，其技术突破决定了我国企业在该领域已达世界技术前沿。比亚迪、宁德时代等企业集中资源，自主研发突破技术壁垒，在国际前沿市场上逐渐超越LG化学、松下等日韩头部企业，在锂电池技术上领跑全球。电池技术的突破主要集中在能量密度

[5] 江苏省汽车工业办公室:《江苏省动力电池产业发展报告（2023）》。
[6] 中商产业研究院:《中国动力电池行业市场前景及投资机会研究报告》。
[7] 严赋憬、李昌瑞:《我国已建成世界上数量最多的充电基础设施体系》,新华社，https://www.gov.cn/lianbo/bumen/202406/content_6957941.htm。
[8] 蔚来：https://www.nio.cn/charger-map。

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的提升、成本的降低和安全性的提高等方面。宁德时代于2022年推出麒麟电池，体积利用率突破了72%，配用三元电芯能量密度可达255Wh/kg，磷酸铁锂电芯系统能量密度可达160Wh/kg，电池包集成度为当时全球最高[9]，被美国《时代》周刊评为2022年度最佳发明。针对新能源汽车锂电池安全问题，比亚迪在2020年推出了“刀片电池”，摆脱了传统动力电池可能会发生的“热失控”噩梦，在安全性方面具有无可比拟的优势。

2．新能源汽车电机与电控系统

中国的驱动电机在功率方面基本能够达到国际水平，但是在同功率条件下存在重量劣势，因此在功率密度上与国际先进水平相比尚存差距。中国新能源汽车电机技术主要聚焦于永磁同步电机（PMSM），比亚迪和方正电机等企业在该类别技术上的研发投入较多。目前我国新能源汽车电机行业需要更多关注材料与制造工艺两方面，以提高电机性能与耐久度。

新能源汽车的电控系统包括电池管理系统（BMS）、电机控制器（MCU）、整车控制器（VCU）等，这些是新能源汽车实现高效运转和安全性能的关键。中国新能源汽车初期的电控技术基本源于传统汽车电控单元，电控软件水平也处于努力追赶的阶段，尚不够成熟。过去一段时期，我国在电控系统中的核心技术与零部件高度依赖进口，如电池管理系统集成电路板上最为核心的电压采集芯片等部件，几乎被美国美信（Maxim）、美国德州仪器（TI）、荷兰恩智浦（NXP）等国际知名企业垄断；电机控制器里面的核心功率半导体IGBT，则被德国英飞凌（Infineon）、美国安森美（On Semiconductor）、日本三菱（Mitsubishi）等几家国际巨头垄断。中国比亚迪等企业近几年通过电控系统技术引进与自主研发，逐步掌握了核心技术，但与世界先进企业的技术水平相比仍存在不小的进步空间。

3．操作系统与智能网联技术

智能网联汽车操作系统逐渐发展为安全车控、智能驾驶和智能座舱3类[10]，智能网联技术是新能源汽车未来发展的重要方向。中国在5G技术、车联网和自动驾驶技术方面的快速发展，为新能源汽车提供了良好的技术支持。华为在智能网联汽车解决方案方面的创新，为中国新能源汽车的智能化发展提供了强大动力。这使得中国的新能源汽车在全球市场上具有较强的竞争优势。

（二）强大的产业链基础造就制造优势

系统集成与高度模块化生产是新能源汽车生产的特征，中国各地区形成了多个新能源汽车制造领域的产业集群。新能源汽车涉及工业领域门类众多，产业链长，覆盖面广，复杂度高，是现

[9] 宁德时代：《集成度全球新高，宁德时代发布麒麟电池》，2022，ttps://www.catl.com/news/6467.html。
[10] 全国汽车标准化技术委员会智能网联汽车分技术委员会：《车控操作系统总体技术要求研究报告（2021）》。

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代工业集成的代表性产业。中国新能源汽车产业链涵盖了从原材料供应、零部件制造、整车生产组装、生产性服务业，车载系统与智能网联应用等多个环节，通过产业链上下游企业的紧密合作，实现了高效的资源配置和联动效应，这是现代产业体系中产业集聚及协同的重要体现。张丹宁等(2024)对上海和广州的研究表明，遵循从“龙头企业引领，协作配套紧密”到“核心技术引领，激发创新活力”再到“创新服务完善”的产业链价值链协同模式，是中国新能源汽车产业集群高质量发展的重要保障。

1.上游原材料供应与零部件生产

新能源汽车原材料的独特性主要在于供应“三电”系统的原材料不同，其余原材料与燃油汽车差异较小。“三电”中的动力电池由正极、负极、隔膜、电解液等组成，关键的正极材料主要以磷酸铁锂和三元锂为主，因而对于锂、钴、镍等电池金属原材料需求巨大。赣锋锂业和天齐锂业等企业通过布局全球原材料供应链，在全球范围内投资锂矿资源，保障了电池生产的原材料供应。驱动电机主要由定子、转子与绕组、端盖等机械结构组成，原材料为稀土磁钢、硅钢片、铜和铝等。电控系统原材料为IGBT功率模块、驱动器、控制器等，其中IGBT在电控系统中是高技术壁垒核心元件。

2.中游零部件制造与组装

中游产业链涵盖电池、电机、电控等关键零部件的制造与组装。电机方面，永磁同步电机是主流类型，在成本结构中，永磁体、定子铁芯、壳体占比前三。电控主要包括电子控制模块(硬件电路和相应的控制软件)、驱动器、功率变换器等模块。其他就是与传统燃油车相近的车身、轮胎、内饰等等，我国燃油车的产业集群发展优势延续到新能源汽车领域，保证了这类通用零部件精良的品质和低廉的成本，从而整体上增强新能源汽车的制造优势。

3.下游整车生产和服务

下游包括整车生产、销售和售后服务等，在整个供应链环节中，高度的区域集聚，信息平台的整合协同优势，为生产与运营提供了有效支持。完备的产业链增强了垂直整合能力，中国企业如华为、百度和小米等纷纷进入市场占有较大份额，还积极开拓国际市场，提升了品牌影响力和市场份额，带来了跨界融合的新机遇。这不仅推动了智能硬件的创新，也促进了从软件到服务的全链条协同发展。

(三)价值链融合开辟广阔发展空间

新能源汽车产业在高度分化的产业链基础上，各环节都有着丰富的衍生产业与附加价值。从汽车自身价值链来看，涵盖了从技术研发与设计、汽车零部件及整车生产制造、物流运输、广告销

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售和售后维修养护等环节。而与汽车相关的周边产业则更为广阔，包括车载平台软件应用，新能源充电基础设施，智能网联车与道路的传感设施，汽车装饰等等。由此形成了以新能源汽车为智慧核心，延伸领域广阔的价值链网络。随着智能网联与自动驾驶技术愈发成熟，新能源汽车将作为未来人居空间的重要场所，解锁更多适用场景，连接最新的应用功能平台。

新能源汽车企业在主价值链的覆盖范围上存在差异，目前主要有三种模式：第一种是全链条布局的厂商，通常由综合实力强大的传统汽车厂商和领先的新进入者组成。这些厂商具备强大的技术研发能力、持续的产品创新力、高效流通体系以及数字化生态系统。第二种模式是专注于终端市场流通、销售和服务的厂商，为上游合作伙伴提供品牌推广、渠道建设、创新服务和用户运营。第三种模式是专注于整车研发、采购和生产制造的厂商，这些厂商以成本控制和供应链管理能力为核心，通过规模化生产制造来实现盈利[⑪]。此外，在价值链的延伸中不断生成更多的价值环节，涌现出众多成长性优秀企业参与建设。

这些价值链环节由点及面形成了一个庞大的价值链网络，“制造+服务”的融合发展模式推动了新能源汽车产业向全产业体系的延展和渗透。作为核心集成应用平台，未来新能源汽车在现代化产业体系中的地位将持续巩固和提升，成为未来产业更新的重要引擎。

四、新能源汽车产业引领和企业创新

中国新能源汽车产业作为战略性新兴产业，近十余年来技术由弱到强，生产规模逐步扩大，成为现代化产业体系中的重要产业之一。从生产制造角度来看，新能源汽车的数字化程度远高于传统汽车，并推动传统汽车产业转型升级和朝向智能化发展。新能源汽车产能规模扩大对产业链上下游企业的技术改造都有着显著的带动和辐射作用。在超大规模市场优势的助力下，更容易形成和维持完备的产业配套和完整的产业体系，进一步丰富新能源汽车产业生态的多样性。

（一）新能源汽车激励传统汽车产业的主动升级

1.技术替代与工艺变革

新能源汽车核心技术替代是电力驱动系统取代了传统内燃机，并以此为基础发展出了汽车新“四化”：电动化、网联化、智能化、共享化。在过去十几年的技术演进中，电池管理系统、电控系统和驱动电机等关键技术逐步成熟，提升了整车的性能和可靠性。新能源汽车的生产需要匹配新的装配技术和检测标准，如电池组装和测试工艺、电机安装工艺等。在汽车实际生产转型中，传统汽车生产线需要进行大规模改造以适应电动汽车的生产需求。

[⑪] 德勤：《中国新能源汽车五大趋势分析与价值链定位模式和战略思考框架解读报告》，2019。

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2.供应链生态的重构与完善

新能源汽车产业在持续适应技术革新与市场需求变动中，重构并持续优化供应链，实现了从上游原材料供应、中游零部件制造到下游整车生产和销售的高度整合。中国在新能源汽车领域形成了完备的产业体系，涵盖了电池、电控、电驱动系统及电子产品和软件的供应体系，充换电和电池回收配套设施也不断完善。中国新能源汽车动力电池装车量占全球市场的60%以上，其中宁德时代、比亚迪等六家企业跻身全球前十，动力电池关键材料如正极、负极、隔膜和电解液的出货量全球占比超过70%。弗迪动力等电驱电控企业在市场规模上全球领先，一批从事高端芯片和智能驾驶系统软硬件研发制造的企业迅速壮大。截至目前，中国累计建设了超过900万个充电基础设施，动力电池回收企业数量已超1.4万家，均位居全球首位。新能源汽车企业通过与整车厂商的紧密合作，显著提升了供应链的效率和透明度，增强了在全球的整体竞争力和抗风险能力。

3.市场与品牌重塑

借助中国超大规模市场优势，新能源汽车的崛起改变了传统汽车市场的竞争格局，迎来了汽车市场和品牌的重塑阶段。借助中国超大规模市场的需求牵引，近年来的新兴新能源造车势力，如蔚来、理想、小鹏、赛力斯以及小米等，逐步成为市场焦点，为消费者所熟知，打破了燃油车时代外资品牌垄断中高端市场的局面。其中，比亚迪2023年全球销量达300万辆，成为全球新能源汽车销量冠军，并首次进入汽车品牌销量前十名，实现了中国品牌的崛起。

（二）推动新能源汽车产业链的数字化转型

数字化转型是提升产业竞争力和效率的重要手段。洪银兴和任保平（2023）指出，需要在数字经济与产业创新深度融合层面，实现创新链与产业链融合，构建数智赋能机制，实现数字产业化与产业数字化融合发展。新能源汽车产业链通过自动化装配、大数据整合、人工智能和物联网等技术的应用，逐步形成了从生产到销售再到售后的全方位数字化转型，成为创新链与产业链构建的重要交汇点。Jie等（2023）研究表明，数字智能转型在发展新的生产功能之外，还可借助消费者加速新能源汽车企业的技术创新。

1.生产过程与供应链数字化

通过应用自动化装配线、智能仓储系统和协同生产管理软件等数字智能化措施，新能源汽车生产线更加智能高效，实现生产排期、物流管理、能耗管理、安全管理、质量检测等环节的优化，在生产速度与良品率等标准上都有了大幅提升。哪吒汽车利用数字仿真、生产过程自动化可视化等手段，提升了数字效益，2022年产能较前一年提升了60%[⑫]。通过大数据和区块链技术，新能源汽

[⑫] 新华网：《生产线更“快”更“聪明” 汽车引领“智”造新方向》，http://www.news.cn/fortune/2023-10/27/c_1129942316.htm。

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车企业能够实现供应链的实时监控，优化库存，提升了供应链的响应速度和可靠性。不同于传统数据湖，即简单将生产环节涉及的设备、人、工具、检验等过程信息存储其中，特斯拉引入互联网“数据中台”概念，打造上海超级工厂数据中台，实现关键数据统一治理。该中台针对用于业务分析的数据，按照数据使用标准，从输入源头上对数据格式、准确度和可靠性做出约束，为质量工作提供即时可用的数据资源。数字化供应链管理不仅提高了效率，也增强了供应链的稳定性和安全性。目前中国汽车以及新能源汽车生产环节的智能化水平已经处于世界先进水平，数字制造技术应用广泛，但在数字化设计和工业软件等个别领域还有较大的技术提升空间。

2.销售和服务数字化

当前传统4S店营销模式正面临着多重挑战：客源少、客户转化率低、营销成本高以及营销创新不足等。由此线上渠道、商场体验店等多元融合营销模式应运而生。新能源汽车企业主要通过电商平台和智能化销售系统进行市场营销活动，有助于销售渠道的拓展和客户服务体验优化。推行线上直销，减少中间环节，提升交易效率的同时，也便于收集和分析消费者行为数据，精准把握市场需求。在售后服务上，新能源汽车同样运用数字平台技术，配合智能化汽车监测系统，实现汽车自动诊断等功能，使得售后服务更加便捷高效。以比亚迪为例，比亚迪的电池监测平台整合了多种云端检测和故障预警算法，能够对不同车型、各种工况和多种故障类型进行全面监管和预警，有效降低售后维护成本的同时，提升电池的使用安全性。在事故响应和网络安全保障方面，比亚迪依托其监管平台、强大的大数据和信息化能力，以及完善的售后服务体系，将监测到的报警信息实时推送至售后端，提供全天候的持续服务。这样确保车辆发生故障时能第一时间联系用户，确认实际情况并提供救援方案，保障车辆使用的安全性。

3.数据驱动的产品精准优化

在5G、区块链和人工智能等技术的支持下，数据平台能够更加及时准确地获取用户身份数据、车辆数据以及用车行为数据。这些丰富的数据加速了平台的迭代速度和服务效率，促进平台对智能汽车产业上下游的精准赋能。比如建立数据驱动的能耗降低策略更新机制，定期对能耗数据进行监测和分析，找出影响续航能力的关键因素，并提出相应的优化措施，及时调整汽车能耗。数据驱动的产品优化，使得新能源汽车企业能够快速响应市场需求，提升产品的竞争力。

（三）新能源汽车重塑中国智慧城市交通网络

新能源汽车通过以数据为纽带的“人—车—路—云”高效协同系统，在智能网联与自动驾驶技术的支持下，推动了城市交通的智能化和可持续发展。基于汽车感知、交通管控、城市管理等多源信息，构建多层数据融合与计算处理平台，使得新能源汽车充分融入城市交通系统，持续扩大应用领域，揭开未来智慧高效出行的序幕。

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智能网联汽车可与路况信息同步，为自动驾驶与路线优化提供支持，当前正处于技术形成阶段。国内城市与企业积极探索合作路径。截至2023年底，全国已建设17个国家级测试示范区、7个车联网先导区、16个智慧城市与智能网联汽车协同发展试点城市[13]。华为致力于成为智能网联汽车的增量供应商，自2013年开始布局车联网及智能驾驶领域，经过多年的研发积累，于2020年发布了智能汽车解决方案品牌HI，涵盖计算与通信架构、智能系统和计算平台。华为与众多车企合作，协力推进车联网平台建设：通过Huawei Inside模式与北汽、长安、广汽等多家车企合作，华为智选模式合作企业则包括赛力斯、奇瑞、江淮等。综合数字交通管理系统能有效调度和优化交通流量，智能控制信号灯，选择最优路线，避免拥堵，提高了整体交通效率。

此外，智能充电网络的建设为新能源汽车提供了便捷的充电服务，充电设备一方面连接能源消费端，另一方面连接能源供给端。车联网与云计算技术的发展使得交通与能源产业紧密结合成为可能，这不仅有助于开发利用交通基础设施内外部的清洁能源资源，推动交通绿色转型，还能使未来的交通网络成为新型电力系统和能源系统的重要储能资源池，实现交通网与能源网的相互支持，有助于提高能源利用效率与可控性。

五、面向未来的发展方向

当前中国新能源汽车产业在国际市场竞争中优势较为明显，在一定程度上实现了“弯道超车”。随着车联网基础设施的完善与自动驾驶技术的成熟，未来新能源汽车在出行中的地位仍将继续提高，因而把握好当前发展阶段，承前启后尤为重要。国际政治博弈和经济波动等因素也给中国新能源汽车产业发展带来诸多不确定性，如欧盟对中国新能源汽车加征关税，美国对高端芯片出口加以限制等。现代化产业体系要求技术自主可控，产业链供应链安全稳定，化解“卡脖子”难题，实现稳中求进。中国新能源汽车产业在实现技术自主可控方面已经先行一步，未来更需及时洞察技术与市场发展趋势，明确主要发展方向。

（一）适时调整策略适应未来市场与规制环境变化

随着自动驾驶与车路协同技术的成熟，消费者对智能汽车的需求将显著增加。新能源汽车企业需及时响应市场新需求，优化设计和性能，保持技术前沿地位。当前新能源汽车的锂电池自燃等事件时有发生，这也是新能源汽车产业不可回避的技术和安全问题。除汽车和电池生产企业在源头加强电池安全技术创新和严格管理外，需要第三方机构在检验检测环节同步加强电池安全管理。在优化电池自身技术，提高安全性能的同时，注重电池系统安全，给予市场与消费者更多信心。

[13] 中华人民共和国工业与信息化部：《关于开展智能网联汽车“车路云一体化”应用试点的通知》解读，https://wap.miit.gov.cn/jgsj/zbys/gzdt/art/2024/art_e7c5417e9d8949f194945fc290f54dc3.html。

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面对日益严峻的气候变化问题，全球各国政府相继出台了严格的环保法规和激励政策，推动清洁能源乘用车及商用车的普及。美国环保署（EPA）在2024年3月宣布了新的更严格的排放标准，减少卡车和公共汽车等重型车辆的温室气体排放，并在2027~2032年的年型车上应用更严格的新标准[14]。欧盟理事会和欧洲议会在2024年初就重型车辆二氧化碳减排目标进行了调整，将现有的2030年减排目标从30%提高到45%，2040年减排90%[15]。这些政策变化驱动了全球范围内新能源商用车的发展，并要求新能源汽车企业在产品设计和制造过程中严格遵守环保法规，降低生产制造中的碳排放。

（二）在开放合作中规范市场主体行为

基于新能源汽车产业庞大的产业链，应在全面考虑政策、资金、人才、土地、基础设施等因素的基础上，在技术创新、市场公平竞争等方面加强开放性制度建设，协同要素资源（刘志彪，2023）。充分发挥国家新能源汽车技术创新中心，中国汽车技术研究中心等头部平台优势，联动企业、高校及研究机构合力开展技术攻关，围绕新能源汽车产业重大需求，加强重大关键技术源头供给，打造世界新能源汽车技术创新的策源地。此外需由头部公共机构与企业牵头，从长远利益角度出发，建设标准制定与数据互通的协作平台，打通技术与信息壁垒，同步开展智能产品测试改进和产业链节能减排，营造兼容互通，绿色节能的产业氛围（肖旭、戚聿东，2024）。避免各大车企及数据集团各自为营，恶性竞争。

当前已进入新能源汽车产业发展新阶段，应加大保障市场参与主体的平等权利，严防垄断行为（白雪洁、孟辉，2018）。新能源头部汽车企业需在严格遵守反垄断法的基础上，避免在供应链、互联网平台、数据使用和专利管理等领域滥用市场支配地位：需对限制配件生产、限制经销商外采外销和限制维修技术信息获取等行为加以调查与管制。在互联网平台方面，需防止利用数据、算法和平台规则排除或限制竞争。此外，车企与互联网企业需合理使用收集到的性能和用户数据，确保信息透明和公平获取，并积极探索专利使用与共享机制。介于新兴的产业市场背景，政府需与企业探索公平竞争的市场策略，确保合规经营，以开放式合作助力新能源汽车产业创新，促进健康发展。

（三）全球化生产布局增强产业韧性

全球化生产布局有助于增强新能源汽车产业的韧性，分散风险，提升竞争力，加强国际合作与共同发展。新能源汽车的生产主要包含动力电池、电控、电机及其他传统汽车零部件，中国

[14] 美国环保署：Final Rule: Multi-Pollutant Emissions Standards for Model Years 2027 and Later Light-Duty and Medium-Duty Vehicles, 2024.
[15] 欧盟：Heavy-duty vehicles: Council and Parliament Reach a Deal to Lower CO2 Emissions from Trucks, Buses and Trailers, 2024.

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企业的优势在电池生产领域最为突出。宁德时代率先组建了全球化电池供应网络，已设立了13座生产基地，其中有两座分别在德国图灵根和匈牙利德布勒森，预计投产后年产能达24GWh及100GWh。宁德时代国内生产基地也分布于全国11个省份，大幅提升了供应效力与抗风险能力。比亚迪也在巴西、泰国、匈牙利等地投资建立海外工厂。支持有实力的新能源汽车企业通过新设、并购和联合投资等方式，在“一带一路”沿线国家建立子公司或分公司，集中优势资源，开拓重点国际市场。鼓励新能源汽车整车、零部件及基础设施企业和相关机构开展国际产能合作和园区建设，在研发、采购等层面开展深度合作，推动产业链协同发展。建立健全企业间的互助合作机制，促进企业在海外市场信息、配套设施、产能合作和销售网络等方面共享资源，形成良性互动。

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Driving Innovation: China's NEV Development Model and Future Outlook

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Abstract: *In recent years, China's new energy vehicle (NEV) industry has emerged as a crucial component of its modern industrial system, drawing on its advantages in technological innovation, industrial scale, and green, low-carbon development. As one of China's strategic emerging industries, the NEV sector is at the forefront of R&D and breakthroughs in critical core technologies. It is a central industry in terms of industrial agglomeration, highly coordinated supply chains, and the expansion of value chains. NEVs are a key representative of China's manufacturing industry expanding globally in the new era. To maintain a competitive edge, it is critical to expedite breakthroughs in key technologies and ensure autonomy and control over the industrial supply chain. Looking to the future, the industry must optimize data-driven "user-vehicle-road-cloud" collaborative systems, adapt to new environmental changes and market demands through open cooperation, and lead the construction and evolution of China's modern industrial system.*

Keywords: *New energy vehicles (NEVs), strategic emerging industries, industrial innovation, industrial chains*

JEL Classification Code: O14, O33

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1. Introduction

The new round of technological revolution and industrial transformation is reshaping the global industrial landscape. To seize the historic opportunities in the context of momentous changes unprecedented in a century, China has embarked on the development of an innovation-driven modern industrial system. This strategic initiative aims to foster emerging technologies like the digital economy, artificial intelligence (AI), new energy, and biotechnology, modernize labor or capital-intensive traditional industries, and enhance overall industrial competitiveness and resilience through digitalization, intelligence, and green technologies (Rui, 2018; Sheng, 2023). China's strategic emerging industries, a cornerstone of its modern industrial system, play a pivotal role in leading the industrial frontier and shaping the future of economic development. As outlined in the *Catalogue of Strategic Emerging Industries* (2023), these industries encompass nine key sectors: new-generation information technologies, high-end equipment manufacturing, new materials, biotechnology, new energy vehicles, new energy, energy conservation and environmental protection, aviation and aerospace, and maritime equipment[1]. As a major strategic emerging industry, the new energy vehicle (NEV) industry overlaps

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[1] The Office of the Leading Group of the Fifth National Economic Census under the State Council: Catalogue of Strategic Emerging Industries (2023).

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and competes with gasoline vehicles for industrial infrastructure and market share. However, with revolutionary breakthroughs in dominant technologies, the NEV industry has significantly transformed the traditional auto industry's techno-economic attributes, evolving into a strategic emerging industry with digital, intelligent, and green characteristics. China's NEV innovative development model features both revolutionary technological breakthroughs and business model innovations. It is also the result of China's extensive industrial clusters and robust market competition.

NEV technological innovations are primarily manifested in the iteration and breakthrough of battery technology, electronic control systems, and intelligent connected vehicle (ICV) technology. NEVs have accelerated energy technology transformation in the automotive sector, reduced reliance on fossil fuels and vehicle emissions, and generated significant environmental benefits to help achieve carbon peak and neutrality goals. Chinese NEV manufacturers have been working with universities and research institutions to overcome technological challenges and achieve new advances in NEV batteries. Specifically, numerous NEV R&D and battery technology projects carried out by enterprises and research institutions, including the *Independent R&D and Large-scale Industrialization of Key Components and Vehicle Platforms for a New Generation of Electric Vehicles* led by BYD and the *Key Technologies for R&D and Manufacturing of Power Batteries for Large-scale Industrialization* led by CATL, have won the second prize for National Scientific and Technological Progress Award in 2023.

The modern industrial system involves the smooth connection and mutual support of the innovation, technology, industry, value and service chains (Bai et al., 2022). The emergence of China's NEV industry has been mainly supported by the innovation and technological chains, which are based on first-mover and economies of scale advantages. In terms of industrial and value chain restructuring, the NEV industrial chain includes battery manufacturing, vehicle manufacturing, and charging facilities, bringing together relevant industries to create a new economic growth driver. China's automotive industrial chain has gradually transitioned from relying on engines, gearboxes, and vehicle axles to focusing on core NEV components like batteries, electrical motors, and electronic control systems. During the gasoline vehicle era, the Chinese government implemented a "market for technology" strategy for the auto industry, opening the country's market to a slew of international carmakers, component and parts manufacturers. International corporations have generated technological and managerial spillovers, accelerating industrial chain development in China. In the era of smart and electric vehicles, however, core parts and components for gasoline vehicles were replaced by critical components for electric vehicles. Domestic enterprises, such as CATL and EVE Energy, have gained a technological advantage in power batteries. Meanwhile, software and hardware vendors for smart vehicles, such as Horizon Robotics and Hesai Technology, have emerged as an important link in the innovation chain. Rapid advances in electrification and intelligence have strengthened China's automotive supply chain, resulting in a "dual circulations" landscape of domestic and international markets. In addition to meeting domestic demand, China's auto industry is becoming increasingly important in the global market (Li et al., 2021). Traditional auto industry revolves around the manufacturing value chain. With the arrival of the intelligent EV era, the service chain has become a new value hotspot, and overall NEV competitiveness is dependent on new service capabilities such as digital financial insurance, electric energy supply, and data service.

This paper examines the fundamental rationale for NEV innovations in light of China's NEV development. Compared to traditional gasoline vehicles, the NEV industry represents a technological breakthrough and leap forward. Integrated innovations in battery technology, electronic control systems, and intelligent connectivity provide the automotive industry with the momentum to seize the opportunities presented by the new generation of technological revolution and industrial transformation. These innovations also drive clustered innovation within the NEV industry. Compared to existing

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literature on the NEV industry, this paper's unique contribution lies in its analysis of how China's NEV sector can drive collaborative innovation across the entire industrial chain through technological advancements, with the conclusions further supported by practical case studies.

2. China's NEV Industry: Status and Characteristics

China's NEV industry started to develop almost concurrently with the international trend. In 1999, the State Council initiated the "Clean Vehicle Initiative", a joint effort by multiple government departments, signaling the start of the low-carbon transition in China's automotive industry. Before 2008, the NEV industry was primarily in the stage of concept formation and industrial preparation. The Ministry of Science and Technology (MOST) launched the "Major Sci-tech Project for Electric Vehicles" under the "863 Program" in 2001, a key initiative aimed at advancing cutting-edge technologies in China, establishing a "three verticals and three horizontals" development framework for EVs. The 'three verticals' represent three powertrain solutions: hybrid vehicles, all-electric vehicles, and fuel-cell vehicles, while the 'three horizontals' include the powertrain control system, electric motor and control system, and battery and management system. This period is marked by NEV technology exploration and industrial incubation. Between 2009 and 2014, China's NEV industry went through a period of strategic formation, technological and market accumulation. During this stage, China implemented the NEV strategy and accelerated the commercialization of new energy vehicles and critical components, with a focus on acquiring dedicated engine and power module optimization design technology, mass production processes, and cost control technologies. In 2010, the Chinese government designated the NEV industry as a strategic emerging industry, calling for breakthroughs in critical technologies such as power batteries, drive motors, and electronic control technologies as generic technologies, as well as the commercialization of plug-in hybrid and all-electric vehicles. *The Energy Conservation and NEV Industry Development Plan* (2012-2020), published in 2012, identified all-electric vehicles as the primary strategic direction of China's NEV industry.

Digital and intelligent transformations, as well as green and low-carbon development, have emerged as clear trends in China's NEV industry. China's leading NEV manufacturers have pioneered independent R&D and manufacturing, forming an endogenous driving force for industrial chain coordination and vertical development. In 2021 and 2022, China's NEV sales volume increased by 157% and 96%, respectively. By 2023, NEVs accounted for more than 30% of China's domestic automobile sales volume on average, with a higher proportion in medium and large cities. China's NEV industry is gaining prominence on the global stage as a result of its innovative development model and ongoing efforts to improve it (Li, 2024).

2.1 Demand-Side Impetus for NEV Innovation and Development

As shown in Figure 1, China has seen a steady increase in NEV consumption and a shift away from gasoline vehicles in recent years. According to the China Association of Automobile Manufacturers[2], China's new energy vehicle production and sales volumes in 2023 reached 9.587 million and 9.495 million units, respectively, up 35.8% and 37.9% from the previous year. China's NEV sales began to rise rapidly in 2020, reaching a market share of 31.6% by 2023, up from a low of 300,000 units in 2016 and a market share of only 1.8%. In 2023, China exported 1.203 million NEV units, accounting for approximately 25% of its total automobile exports, a 3% increase from 2022. In 2023, global NEV

[2] China Association of Automobile Manufacturers (CAAM), http://www.caam.org.cn/tjsj.

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sales were close to 1.4 million units, with China accounting for 60%, Europe for 25%, and the United States for 10%. Without a doubt, China has the largest NEV consumer market in the world. In terms of exports, China's NEVs do particularly well in emerging and developing economies. Between 2022 and 2023, Chinese NEVs accounted for 40% to 75% of electric vehicle sales volumes in Indonesia, Thailand, and Brazil. With the introduction of more affordable models, this sales volume is expected to rise further[3]. According to the *International Energy Agency's (IEA) Global EV Outlook 2023*[4], global EV sales are expected to exceed 70 million units by 2030, bringing the total number of EVs to 380 million, with an annual new vehicle penetration rate of more than 60%. The massive demand potential will undoubtedly drive NEV development.

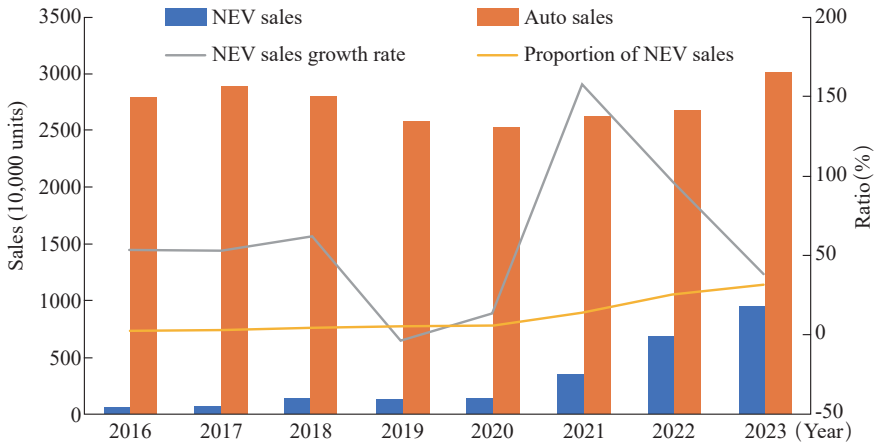

Figure 1: China's NEV Sales Volume, Growth and Percentage (2016-2023)

Source: Drafted by authors based on data from the China Association of Automobile Manufacturers (CAAM), http://www.caam.org.cn/tjsj.

2.2 Regional Specialization in the NEV Industrial Chain

According to the industrial spatial layout, China's NEV industry is characterized by multi-node clustering and belt distribution, with the majority concentrated in the Yangtze River Delta, Pearl River Delta, Chengdu-Chongqing, and Beijing-Tianjin-Hebei regions. Each industrial cluster has a relatively complete industrial supply chain system, indicating a transition from chain to network development. The Yangtze River Delta is a major NEV manufacturing cluster in China. This region has developed a "four-hour NEV industrial circle" made up of localities with distinct advantages: Shanghai produces the chips and software that make up the brains of NEVs, Jiangsu provides power batteries, Zhejiang provides integrated diecasting machines, and Anhui specializes in final assembly. The complete NEV industrial chain is established within a four-hour circle. In terms of automaker distribution, Shanghai is home to SAIC Motor and Tesla, Jiangsu and Anhui host NIO, Li Auto, Chery, and JAC, and Zhejiang is home to the GEELY Group and some newcomers like Leapmotor. The Pearl River Delta Economic Belt is a key region for NEV manufacturing, home to major companies such as BYD and the GAC Group. BYD manages the entire industrial chain, from vehicle manufacturing to power battery, electric motor, electronic control system, and automotive aftermarket. It has manufacturing facilities in several cities throughout the country. The NEV industrial chain and clustered development pattern had already begun

[3] IEA (2024), Global EV Outlook 2024, IEA, Paris https://www.iea.org/reports/global-ev-outlook-2024.
[4] IEA (2023), Global EV Outlook 2023, IEA, Paris https://www.iea.org/reports/global-ev-outlook-2023.

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to take shape in its early stages. It has some similarities with, but goes beyond, the gasoline vehicle industrial clusters.

2.3 China's Emergence As a Major Source of Global NEV Power Battery

China has developed several important industrial clusters for NEV battery manufacturing. According to data from the China Automotive Power Battery Industry Innovation Alliance (CAPBIIA), China's cumulative installed capacity of power batteries reached 387.7 GWh in 2023, a 31.6% increase over the previous year. Chinese enterprises account for approximately 65% of total installed capacity worldwide. Leading Chinese power battery manufacturers include CATL, BYD, China Aviation Lithium Battery (CALB), and Gotion High-tech, which are primarily distributed in southeastern China's coastal regions. Suzhou and Wuxi in Jiangsu Province have established major battery manufacturing sites by implementing advanced manufacturing technology and increasing R&D spending. Jiangsu Province remained China's leader in power battery manufacturing capacity, output, and sales volume in 2023[5]. Jiangsu's power battery industrial clusters follow a coordinated regional development model that includes Changzhou and Nanjing as distribution hubs, Wuxi and Nantong as materials and equipment hubs, and Yancheng, Suzhou, and Zhenjiang as multiple supporting nodes. Changzhou, a new energy town, is home to the headquarters of CALB and Honeycomb Energy, two leading manufacturers of new energy batteries. According to incomplete statistics, Jiangsu has 69 lithium battery industrial hubs, 19 of which are located in Changzhou[6].

2.4 Enhancing Infrastructure and Industrial Development Environment

Charging infrastructure is critical to NEV adoption and user convenience. By May 2024, China's total charging facilities increased by 56% to 9.924 million units. China has established the world's largest and most extensive EV charging infrastructure system, covering major cities and highways across the country, with plans to expand the number of charging stations in the future. In addition, battery swap stations, a new and convenient charging model, are rapidly being deployed and built. In 2023, China added 1,594 battery swap stations, bringing the total number of completed stations to 3,567[7]. NIO has taken the lead in the development of battery swap stations, with 65% of the market share. By June 2024, NIO has built over 2,400 battery swap stations nationwide, providing more convenient power supply services[8].

3. Innovative Development Model of China's NEV Industry

3.1 Pursuing Autonomy and Control over Key Technologies through Independent Innovation

China's NEV industry is primarily market-driven, with an emphasis on independent innovation of key technologies. From the very beginning of its development, China has chosen a path of independent innovation for the "three electrics" technologies—battery, electric motor, and electronic control—which together account for 50% of the cost of NEVs. Furthermore, ongoing efforts have been made to improve the level of independent innovation in high-end component design and manufacturing, as well as ICV technology. According to the *New Energy Vehicle Industry Development Plan* (2021-2035), China

[5] Jiangsu Province Automotive Industry Office: Jiangsu Province Power Battery Industry Development Report (2023).

[6] China Business Industry Research Institute: "China's power battery industry market prospects and Investment Opportunities Research Report".

[7] Yan Fuying, Li Changrui: "Our country has built the largest charging infrastructure system in the world", Xinhua News Agency, https://www.gov.cn/lianbo/bumen/202406/content_6957941.htm.

[8] NIO: https://www.nio.cn/charger-map.

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aims to achieve internationally advanced levels in core technologies for new energy vehicles by 2025, including power batteries, drive motors, and in-vehicle operating systems.

3.1.1 Power battery R&D and application

Chinese companies have made technological advances in power batteries, leading the world in this critical NEV component. In the international frontier market, Chinese companies such as BYD and CATL have concentrated resources and overcome technological barriers through independent R&D, gradually surpassing leading Japanese and Korean companies like LG Chem and Panasonic, and establishing themselves as global leaders in lithium battery technology. Technological breakthroughs have increased energy density, reduced costs, and improved the safety performance of power batteries. CATL launched the Kirin battery in 2022, with a volume utilization ratio of more than 72%. The energy density of a Kirin battery with a ternary battery cell is 255Wh/kg, while one with phosphate iron lithium is 160Wh/kg[9]. Kirin battery was named the best invention of 2022 by Time magazine due to its high level of battery pack integration at the time. In 2020, BYD introduced the "blade battery" to address NEV lithium battery safety concerns. This technology eliminates the "thermal runaway" problem with conventional power batteries, providing unparalleled advantage in safety.

3.1.2 NEV electric motors and electronic control systems

Despite their international performance, China's drive motors are heavier in terms of unit power and have a lower power density. The permanent magnet synchronous motor (PMSM) is the primary electric motor technology for China's NEVs, and companies such as BYD and Founder Motor have made significant R&D investments. China's NEV electric motor manufacturers should improve motor performance and durability by upgrading material performance and manufacturing processes.

The new energy vehicle's electronic control system consists of the Battery Management System (BMS), Motor Controller Unit (MCU), and Vehicle Control Unit. These are critical to achieving efficient operation and safety in NEVs. In the early stages, China's NEV electronic control technology was modeled after the electronic control unit (ECU) of gasoline vehicles, and NEV electronic control software lagged behind international standards. For the past few years, China has relied on imported core technologies and components for its electronic control system. For example, international companies such as Maxim, Texas Instruments (TI), and NXP of the Netherlands dominated the market for critical components such as the power voltage collection chip of the integrated circuit board of the battery management system. Infineon of Germany, On Semiconductor of the United States, and Mitsubishi of Japan hold the monopoly on Insulated-Gate Bipolar Transistor (IGBT) for motor control devices. China's BYD and other companies have taken steps to acquire core technologies in electronic control systems through importation and independent R&D, but there is still much room for improvement when compared to internationally advanced levels.

3.1.3 Operating systems and ICV technology

ICV operating systems are classified into three types of technology: vehicle safety control, intelligent driving, and intelligent cockpit[10]. ICV technology is a key direction for future NEV development. China's rapid development of 5G technology, connected vehicles, and autonomous driving

[9] CATL: The world's highest level of integration, CATL released Kirin Battery, 2022, https://www.catl.com/news/6467.html.

[10] ICV Sub-Committee of the National Technical Committee of Auto Standardization: Research Report on General Technical Requirements of Vehicle Control Operating System (2021).

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technology provides favorable technological support for NEVs. Huawei's innovation in ICV solutions adds significant dynamism to China's development of intelligent NEVs. This gives China's NEVs a significant competitive advantage on the global market.

3.2 Strong Industrial Chain Fundamentals Create Manufacturing Advantage

NEV manufacturing is distinguished by industrial clustering and modularization. Many NEV industrial clusters have been established in various locations throughout China. The NEV industry spans multiple industrial sectors and is a prime example of modern industrial integration, with long industrial chains, broad coverage, and high complexity. China's NEV industrial chains encompass a wide range of processes, including raw material supply, parts, components, vehicle assembly, producer services, on-board systems, and ICV applications. Close collaboration between upstream and downstream enterprises has resulted in efficient resource allocation and synergy, a key manifestation of industrial clustering and coordination in the modern industrial system. According to a study on Shanghai and Guangzhou conducted by Zhang et al. (2024), China's NEV industrial and value chain coordination model has evolved from "dominance by leading enterprises and close collaboration with upstream suppliers" to "breakthroughs in core technologies that inspire innovation dynamism" and "improving innovation services", which underpin the high-quality development of NEV industrial clusters in China.

3.2.1 Raw material supply and component manufacturing

NEVs require unique raw materials for their batteries, electric motors, and electronic control systems, while other materials are similar to those used in gasoline vehicles. The power battery consists of anode, cathode, separator, and electrolyte, with key cathode materials being primarily lithium iron phosphate and ternary lithium. This has led to a huge demand for raw materials such as lithium, cobalt, and nickel. Companies such as Ganfeng Lithium and Tianqi Lithium have strategically invested in lithium ore reserves across the globe, ensuring a steady supply of raw materials for battery production. The drive motor is made up of mechanical structures like the stator, rotor, windings, and end caps, which require raw materials like earth magnets, silicon steel sheets, copper, and aluminum. The raw materials for the electronic control system include the IGBT power module, EV drive, and controller. Among them, the IGBT is a core component with high technological barriers in the electronic control system.

3.2.2 Midstream parts and components manufacturing and assembly

Midstream industries include the manufacture and assembly of critical parts and components such as batteries, electric motors, and electronic control systems. The most common type of motor is permanent magnet synchronous motors. The three most expensive components are permanent magnets, stator cores, and housings. The electronic control module (electric circuit and control software), EV drive, and power converter are the three main components of an electronic control system. Other components include bodywork, tires, and interior decor similar to those found in gasoline vehicles. The clustered development advantage of China's auto industry has been extended to the NEV industry, ensuring the high quality and low cost of such generic components while also strengthening China's overall NEV manufacturing advantage.

3.2.3 Downstream vehicle manufacturing and services

Vehicle manufacturing, sales, and aftermarket services are examples of downstream NEV sectors. The high degree of regional agglomeration, combined with the advantage of an integrated and collaborative information platform, provides effective support to manufacturing and business operations

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across the supply chain. Complete industrial chains have helped to improve vertical integration capabilities. Chinese companies such as Huawei, Baidu, and Xiaomi have entered the NEV market and accumulated a sizable market share. They have also taken proactive steps to expand into the international market, increasing their brand influence and market share while also creating new opportunities for cross-sectoral integration. This has prompted innovation not only in intelligent hardware, but also in the coordinated development of the industrial chain, from software to services.

3.3 The Integration of Value Chains Drives Future Development

The NEV industry is built on highly decentralized industrial chains, with numerous derivative industries and value addition in each sector. The NEV value chains encompass a wide range of links, including R&D, automotive parts and components, vehicle manufacturing, logistics, transportation, advertising, sales, and aftersales maintenance. Automotive peripheral industries are even more diverse, encompassing onboard platform software applications, new energy charging infrastructure, ICV and road sensors, and automotive decorations. These industries form an intelligent NEV value chain network that extends across a wide range of sectors. As intelligent networking and autonomous driving technologies become increasingly mature, NEVs will serve as an important part of future living spaces, unlocking more applicable scenarios and connecting to the latest application platforms.

NEV enterprises can be categorized into the following three business models in terms of their disparate main value chain coverage: First, complete-chain automakers. They include well-established traditional automakers with NEV business expansion and leading new entrants. Those automakers possess strong R&D capabilities, continuous product innovations, efficient distribution systems, and digital ecosystems. Second, distribution, sales and service-oriented auto companies that provide upstream partners with brand promotion, channel development, innovation services, and user operations. Third, automakers focused on vehicle R&D, procurement and manufacturing. With core competencies in cost control and supply chain management, such automakers profit from mass manufacturing[11]. In addition, an increasing number of value processes are generated through value chain extension, giving rise to numerous growth enterprises that contribute to value chain development.

These value chain links have created a massive value chain network, and the integrated "manufacturing and service" development model has accelerated NEV expansion and penetration throughout the industrial system. As a core integrated application platform, the NEV industry will continue to strengthen its position in the modern industrial system, acting as a key driver of future industrial renewal.

4. NEV Industrial Transformative Effect and Corporate Innovation

As a strategic emerging industry, China's NEV industry has grown from a fledgling to a powerhouse over the last decade, becoming a pillar of China's modern industrial system with increased manufacturing capacity. From a manufacturing standpoint, NEVs are far more digitalized than conventional vehicles, accelerating the transition, upgrade, and intelligence of the traditional auto industry. NEV capacity expansion has a significant impact on the technological upgrading of upstream and downstream enterprises. China's massive market is ideal for developing and maintaining comprehensive industrial capabilities and systems, adding to the diversity of the NEV industrial ecosystem.

[11] Deloitte, Report on the Analysis of China's Five NEV Trends and Value Chain Positioning Model and Interpretation of Strategic Reflection Framework, 2019.

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4.1 NEVs Spur Conventional Auto Industry to Upgrade

4.1.1 Technology substitution and process change

As a core technology substitution, NEVs have replaced traditional internal combustion engines with electric drive systems, evolving automobiles' "four new features": electrification, connected vehicle, intelligence, and shared use. Over the last decade of technological advancement, the sophistication of battery management systems, electronic control systems, and drive motors has improved vehicle performance and reliability. NEV production necessitates new assembly technologies and testing standards, such as the battery assembly and testing process and the motor installation process. The conventional automobile production line must be overhauled to meet the needs of NEV manufacturing.

4.1.2 Supply chain ecosystem restructuring and improvement

The NEV industry has rebuilt and continuously improved supply chains to keep up with technological advancements and changing demand. This has resulted in a high level of integration between upstream raw material supply, midstream parts and component manufacturing, and downstream vehicle production and sales. China has established a comprehensive industrial system in the NEV sectors, including batteries, electronic control and electric drive systems, electronic products, and software. Charging, battery swap, and battery recycling facilities have all undergone continuous improvements. China's NEV battery installed capacity exceeds 60% of the global total. Six Chinese companies, including CATL and BYD, are ranked among the top ten power battery manufacturers worldwide. China shipped more than 70% of the world's critical power battery materials, including anodes, cathodes, diaphragms, and electrolytes. Election Drive and electronic control companies, such as FinDreams Powertrain, dominate the global market, and many high-end chip and smart driving system software and hardware manufacturers have thrived. China has built over 9 million charging stations in total, as well as more than 14,000 power battery recycling companies, both of which rank first globally. NEV enterprises have significantly increased supply chain efficiency and transparency, as well as their global competitiveness and risk resilience, by working closely with OEM manufacturers.

4.1.3 Market and brand reshaping

Leveraging China's massive market advantage, the rise of NEVs has transformed the competitive landscape of the traditional automotive market, ushering in a new era of automotive market and brand reshaping. Driven by China's massive demand, emerging NEV forces such as NIO, Li Auto, SERES, and Xiaomi have risen to the forefront of the automotive market, becoming household names and breaking foreign brands' monopoly on mid- and high-end auto market segments in the gasoline vehicle era. Among them, BYD achieved global sales of 3 million electric vehicles, becoming the world's top-selling electric vehicle brand and entering the top ten list of automotive brand sales for the first time, marking the rise of Chinese brands.

4.2 Propelling the Digital Transition of NEV Industrial Chain

Digital transition is an important means of increasing industrial competitiveness and efficiency. According to Hong and Ren (2023), integrating innovation and industrial chains is critical to achieving synergy between the digital economy and industrial innovation, as well as creating a digital intelligence empowerment mechanism for the integrated development of digital industrialization and digitalization. The NEV industry has achieved a comprehensive digital transition from production to sales and aftersales service by utilizing automated assembly, big data integration, artificial intelligence (AI), and

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the Internet of Things (IoT), among other technology applications. According to Jie et al. (2023), digital intelligent transformation can accelerate NEV innovations by leveraging consumers in addition to developing new production capabilities.

4.2.1 Digitalization of production process and supply chains

The NEV production line has become smarter and more efficient as a result of digital intelligence measures such as automated assembly lines, intelligent warehousing systems, and collaborative production software. This has improved a variety of aspects, including production scheduling, logistics management, energy consumption management, safety management, and quality inspection, resulting in significant improvement in productivity and product quality. Neta Auto used digital simulation and automated visualization of the manufacturing process to improve digital efficiency, increasing production capacity by 60% in 2022 over the previous year[12]. Big data and blockchain technology enable NEV companies to achieve real-time supply chain monitoring, optimize inventory, and improve supply chain responsiveness and reliability. Unlike traditional data lakes, which only store information about equipment, people, tools, inspections, and other production processes, Tesla has used the concept of an "Data Middle Platform" and built such a "platform" for its Shanghai Gigafactory, achieving unified governance of key data. This data mid-end platform, designed for data used in business analysis, imposes constraints on data format, accuracy, and reliability from the input source in accordance with data usage standards, ensuring that data resources are readily available for quality work. Digital supply chain management not only improves efficiency, but it also increases supply chain stability and security. China is a world leader in the intelligent manufacturing of automobiles and NEVs, with widespread application of digital manufacturing technologies. However, there is still a lot of room for improvement in digital design and industrial software.

4.2.2 Sales and service digitalization

The traditional 4S (sales, spare parts, service, and survey) dealership marketing model faces multiple challenges, including a lack of customers, a low conversion rate, high marketing costs, and insufficient marketing innovation. As a result, a new marketing model is emerging that incorporates a variety of elements, including online channels and experienced stores in shopping malls. NEV businesses engage in marketing activities through e-commerce platforms and intelligent sales systems, which help to expand sales channels and improve customer service. Online direct sales and the elimination of intermediaries have increased transaction efficiency while also making it easier to collect and analyze consumer behavior data in order to capture market demand. In terms of aftersales service, NEVs also utilize digital platform technology, in conjunction with intelligent vehicle monitoring systems, to achieve functions such as automatic vehicle diagnostics, making after-sales service more convenient and efficient. Taking BYD as an example, the company's battery monitoring platform incorporates a variety of cloud-based detection and fault warning algorithms, allowing for comprehensive monitoring and early warning for a variety of vehicle models, operational conditions, and fault types. This significantly reduces after-sales maintenance costs while improving battery safety. In terms of incident response and cybersecurity assurance, BYD delivers alarm information to the after-sales team in real time, ensuring continuous 24/7 service. This function is achieved through a combination of its monitoring platform, strong big data

[12] Xinhua: "Faster" and "smarter" production line, cars lead the new direction of "intelligent" manufacturing,http://www.news.cn/fortune/2023-10/27/c_1129942316.htm.

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and information technology capabilities, and comprehensive after-sales service system. When a vehicle breaks down, the system will immediately contact the user to confirm the incident and provide a rescue plan, ensuring the safety of vehicle operation.

4.2.3 Data-driven product optimization

Data platforms that use 5G, blockchain, and AI technologies can acquire user ID, vehicle data, and driving behavior data more quickly and accurately. Such a wealth of data can be harnessed to speed up platform iteration and service efficiency, promoting precise empowerment of the upstream and downstream of the intelligent automotive industry. For example, a data-driven energy efficiency mechanism can be established to monitor and analyze energy consumption data in order to identify critical impediments to vehicle range and propose optimization measures to reduce energy consumption. Data-driven product optimization allows NEV companies to respond quickly to market demand and increase their competitiveness.

4.3 NEV Industry Reshapes China's Transportation Network for Smart Cities

Based on the data-linked "User-Vehicle-Road-Cloud" Integration System, NEVs contribute to intelligent and sustainable development of urban transportation, which has been aided by ICV and autonomous driving technologies. Multi-tiered data integration and computing platforms are developed using information from vehicle sensing, traffic control, and urban management to integrate NEVs into the urban transportation system and broaden their applications, ushering in a new era of intelligent and efficient transportation.

Intelligent connected vehicles (ICVs), which are still in the technology development stage, facilitate autonomous driving and path optimization by synchronizing traffic data. Chinese cities and businesses have been actively seeking opportunities for collaboration. By the end of 2023, China had built 17 state-level ICV test experiment zones, seven connected vehicle pilot zones, and 16 pilot cities to coordinate the development of smart cities and ICVs[13]. Huawei serves as an incremental supplier of ICVs. Since 2013, it has conducted extensive research and development on connected vehicles and intelligent driving. After many years of R&D, it launched the intelligent vehicle solution brand HI in 2020, which includes computing and communications architecture, intelligent systems, and a computing platform. Huawei has collaborated with several automakers to create connected vehicle platforms. For example, it has collaborated with the BAIC Group, Changan Automobile, and the GAC Group under the Huawei Inside model, and SERES, Chery, and JAC under the Huawei Smart Selection model. The integrated digital transportation management system can efficiently dispatch and optimize traffic flows, control traffic signals, and choose the best path to avoid congestion and increase traffic efficiency.

Furthermore, the intelligent charging network connects energy consumers and suppliers, making charging services for NEVs more convenient. Advances in ICV and cloud computing technologies have enabled the integration of transportation and energy sectors. In addition to leveraging clean energy resources within and beyond the transportation infrastructure to accelerate the green mobility transition, ICV and cloud computing technologies are transforming the future transportation network into a major energy storage solution. Mutual support between transportation and energy networks improves energy efficiency and controllability.

[13] Ministry of Industry and Information Technology of the People's Republic of China, Interpretation of the "Notice on Carrying Out Pilot Applications of 'Vehicle-Road-Cloud Integration' for Intelligent Connected Vehicles", https://wap.miit.gov.cn/jgsj/zbys/gzdt/art/2024/art_e7c5417e9d8949f194945fc290f54dc3.html.

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5. Future Outlook

The Chinese new energy vehicle industry holds a relatively significant advantage in the international market competition, achieving a degree of "overtaking on the curve". Improving ICV infrastructure and autonomous driving technology will further highlight NEVs' future role. To capitalize on future opportunities, China must prioritize NEV development. Geopolitics and economic volatility have also created uncertainties in China's NEV industry. For example, the European Union has increased tariffs on Chinese NEVs, while the United States has restricted high-end chip exports to China. Technological independence and self-reliance are required to build a modern industrial system. In this regard, it is critical to ensure industrial and supply chain security and stability, overcome technological bottlenecks, and pursue research advancements. China's NEV industry has already taken the first steps towards technological independence and self-reliance. Moving forward, it must identify and keep up with technological and market development trends.

5.1 Timely Adjusting Strategies to Adapt to Changing Market and Regulatory Environment

Consumer demand for intelligent vehicles is expected to rise significantly as autonomous driving and vehicle-road integration technologies advance. To maintain technological leadership, NEV enterprises must respond quickly to new market demands while also optimizing design and performance. The spontaneous combustion of lithium batteries creates an unavoidable technological and security issue for the NEV industry. While automakers and battery manufacturers should improve battery security innovations and management, third-party institutions must also strengthen battery safety management during testing procedures. In addition to optimizing battery technology and increasing safety performance, automakers should boost market and consumer confidence in battery safety.

Governments have enacted stringent environmental regulations and incentive policies to encourage the adoption of clean energy passenger and commercial vehicles in response to the growing severity of climate change. The Environmental Protection Agency (EPA) issued stricter emissions standards in March 2024 to reduce greenhouse gas emissions from heavy-duty vehicles such as trucks and buses, with the new standards to be applied to model years 2027 through 2032[14]. In early 2024, the Council of the European Union and the European Parliament adjusted the CO2 emissions reduction targets for heavy-duty vehicles, raising the current 2030 emissions reduction target from 30% to 45% and then to 90% in 2040[15]. Such policy shifts have accelerated the global development of new energy commercial vehicles, necessitating strict compliance with environmental regulations in product design and manufacturing processes, as well as a reduction in carbon emissions.

5.2 Regulating Market Entities through Opening-up and Cooperation

Given the vast NEV industrial chain, the government should promote open institutional development in terms of technological innovation and fair market competition in order to coordinate factor resources based on a comprehensive consideration of policy, capital, talent, land, and infrastructure factors (Liu, 2023). It is critical to highlight the importance of leading platforms like the National New Energy Vehicle Technology Innovation Center (NEVC) and the China Automotive Technology and Research Center (CATARC). Enterprises, universities, and research institutions should collaborate to conduct research and development, increase the supply of critical technologies for the NEV industry, and

[14] US EPA: Final Rule: Multi-Pollutant Emissions Standards for Model Years 2027 and Later Light-Duty and Medium-Duty Vehicles, 2024.

[15] The European Union: Heavy-duty vehicles: Council and Parliament reach a deal to lower CO2 emissions from trucks, buses and trailers, 2024.

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establish R&D centers for global NEV innovations. Furthermore, leading public institutions should work together with businesses to create collaboration platforms for standardization and data connectivity, remove technological and information barriers, conduct intelligent product testing and improvement, conserve industrial chain energy and reduce emissions, and foster an industrial environment of compatibility, connectivity, and energy efficiency (Xiao and Qi, 2024). Automakers and data groups should avoid siloed operations and destructive competition.

As the NEV industry enters a new development stage, it is critical to protect market participants' equal rights and prevent monopolistic behavior (Bai and Meng, 2018). Leading NEV companies must strictly adhere to anti-monopoly laws and avoid abusing their market dominance in supply chains, Internet platforms, data usage, and patent management. They should investigate and address anti-competitive practices such as limiting parts and component manufacturing, restricting dealer purchasing and sales, and withholding repair technology information. Regulatory authorities should prevent internet platforms from abusing data, algorithms, and platform rules to exclude or limit competition. Additionally, automakers and internet companies should responsibly utilize performance and user data, ensuring information transparency and fair access. They should also actively explore patent use and sharing mechanisms. To ensure the healthy development of the emerging NEV market, the government must collaborate with businesses to implement fair competition strategies, enforce regulatory compliance, and support open innovation.

5.3 Globalized Manufacturing Distribution Increases Industrial Resilience

A globalized production layout helps enhance the resilience of the new energy vehicle industry, diversify risks, boost competitiveness, and strengthen international cooperation and mutual development. China's NEV manufacturing sector encompasses power batteries, electronic control units, electric motors, and traditional automotive components. Notably, Chinese companies hold a significant advantage in battery manufacturing. CATL led the way in establishing a global battery supply network, with 13 manufacturing sites, including two in Thuringia, Germany, and Debrecen, Hungary. Once operational, the annual production capacity is expected to be 24GWh and 100GWh. CATL's domestic manufacturing sites are spread across 11 provinces, significantly improving supply efficiency and risk resilience. BYD has also invested in foreign factories in Brazil, Thailand, Hungary, and other countries. Competitive NEV companies should be assisted in establishing subsidiaries or branches in countries participating in the Belt and Road Initiative (BRI) through new establishments, mergers, and joint investments, focusing superior resources on exploring key international markets. Automakers, parts and component manufacturers, and infrastructure companies in the NEV industry, as well as relevant institutions, are encouraged to engage in international capacity cooperation, jointly construct industrial parks, and conduct R&D and procurement cooperation to promote coordinated industrial chain development. Enterprises should establish mutual assistance and cooperation mechanisms to share overseas market information, supporting facilities, production capacity, and sales networks, thereby creating positive interactions.

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