中国新能源产业发展特征及竞争优势

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摘　要：近年来，随着中国能源“新三样”产品在全球的畅销，西方一些媒体、政客频繁炒作我国新能源“产能过剩论”，并积极推动相关国家采取对新能源产品实施反补贴调查、提高关税等违背自由贸易精神的措施。针对这些现象，本文阐释了中国新能源产业发展壮大对世界发展的三大贡献，归纳总结中国新能源产业发展的三个演变特征，深入分析中国新能源产业竞争力七大来源，提出新能源产业高质量发展的政策建议，相关结论对于回应西方国家相关质疑提供了事实依据。

关键词：新能源产业　发展特征　竞争优势　碳排放

JEL 分类号：Q43，Q47，O13

一、引言

近年来，中国新能源产品日益受到世界各国消费者青睐。我国光伏组件产量已连续16年位居全球首位，多晶硅、硅片、电池片等组件的产量和产能的全球占比均达80%以上(张悦，2024)。新能源汽车实现了从全球汽车产业“追赶者”到“引领者”的蜕变，2023年，中国新能源汽车在全球市场的占有率已达65%-68%，预计到2025年，这一数字有望攀升至70%以上。据海关总署发布的数据显示，2023年，我国能源“新三样”(新能源汽车、锂电池、光伏产品)产品[①]合计出口首次突破万亿元大关(林水静，2024)。

然而，为了遏制中国新能源产业发展，西方一些媒体、政客近期频繁炒作“产能过剩论”。美国财政部部长耶伦曾多次谈及中国新能源产业存在所谓“产能过剩”问题。2024年5月，美国政府在现有的301条款关税基础上，对中国进口电动汽车、光伏产品和锂电池的关税分别提高到100%，50%和25%。欧盟委员会(以下简称“欧委会”)在没有任何业界申请的前提下，启动了针对中国电动汽车的反补贴调查。调查尚在进行中，欧委会就已经对在欧洲销售的中国电动汽车进行备案，作为日后处罚回溯的依据。此外，欧委会又依据《外国补贴条例》在光伏领域开启反补贴调查，其中涉及中国企业。

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① 本文中新能源汽车指电动汽车或者电动载人汽车；光伏产品主要指太阳能蓄电池。

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诚然，以上言论不符合基本事实，反补贴调查、提高关税的做法也违背自由贸易精神，可能对全球能源转型产生不利影响。这种言论的根源在于某些国家对中国新能源产业的全球贡献、发展历程、产品竞争力来源等缺乏清晰认识。而以往学者重点关注我国新能源产业发展特征（陈思梦等，2022；胡东欧，2022；李景云，2024）、竞争优势(韩忠楠，2024;李长升，2023；刘叶琳，2024；杨武、宋晓晴，2024)以及如何应对贸易壁垒（郭蓉、李元琨，2024；段世德，2015）等方面。少有研究系统论述能源“新三样”出口的竞争优势，因此无法有效回应国际上一些国家对我国新能源产业竞争力的质疑。鉴于此，本文提炼中国新能源产业对全球发展的三大贡献，归纳中国新能源产业的演变特征，总结中国新能源产业七大竞争优势，最后指出我国新能源产业高质量发展的应对策略。

二、中国新能源产业发展的世界贡献

新能源因其分布广、潜力大、低碳环保等特点，成为世界各国应对气候变化的重要选择。为实现节能减排和“双碳”目标，中国政府大力支持发展以新能源汽车、锂电池及光伏发电为代表的新能源产业。而这一发展战略对于中国乃至世界都至关重要。

（一）中国新能源产业发展壮大是对全球碳减排目标的重要贡献

首先，在全球气候变化和环境保护日益成为国际共识的背景下，减少二氧化碳排放和应对气候变化，已成为各国共同面对的重大挑战(范秋芳等，2024)。中国是世界上最大的碳排放国，能源结构长期以煤炭为主，这给中国经济可持续发展带来了巨大的压力。因此，推进能源结构转型，大力发展新能源产业，成为中国履行国际责任，实现碳减排目标的重要途径。

其次，中国碳排放占全球三分之一，通过发展新能源取代煤炭等化石能源将会直接有助于减少世界碳排放总量。2022年，中国可再生能源发电量的大幅增长，减少了国内约22.6亿吨二氧化碳排放（叶书宏，2024），为全球碳减排作出了巨大贡献。

再次，中国通过“新三样”出口，帮助其他国家节约能源资源，也间接促进了全球碳减排。据估算，2022年中国出口的风电、光伏产品帮助其他国家减少了约5.73亿吨二氧化碳排放，相当于全球同期可再生能源折算减排量的41%（叶书宏，2024）。

因此，中国是推动全球可再生能源产业发展的最大贡献者（董梓童，2024），中国新能源产业发展壮大不仅减少本国碳排放，还间接减少他国碳排放，为世界温控目标的实现提供了重要支持。

（二）中国新能源产品贸易激发世界经济活力，促进国际产业链合作

首先，中国新能源产业的发展满足了全球清洁能源的需求，带动了国际贸易的繁荣。随着全

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球对清洁能源需求的不断增长，中国新能源产品的出口量迅速提升。中国凭借其在新能源汽车、锂电池、太阳能电池等领域的领先地位，为全球各国提供了大量的清洁能源解决方案。例如，中国的太阳能电池企业在东南亚、非洲等地区建设了多个生产基地和太阳能电站项目，不仅满足了当地的能源需求，也促进了当地的经济发展和就业。中国的新能源汽车企业也在欧洲、东南亚等地区设立了生产工厂和研发中心，加强了与当地企业的合作，推动了全球新能源汽车产业的发展。目前，能源“新三样”产品凭借其高附加值、高增长性和广阔的市场前景，已成为全球经济新的增长点。新能源产品出口不仅促进了国际贸易的繁荣，还加强了国际间的经济联系与合作，为全球经济一体化注入了新的活力，加速推动了世界经济的复苏与增长。

其次，中国新能源产品贸易的发展促进了国际产业链的深度合作。在新能源领域，中国已经与多个国家和地区建立了紧密的合作关系，共同推动新能源产业的发展。这种合作不仅体现在产品贸易上，还涉及到技术研发、产业链整合、市场开拓等多个方面。通过与国际合作伙伴的紧密合作，中国新能源企业加速融入全球产业链，提高国际竞争力。同时，这种合作也为全球新能源产业的协同发展提供了有力支撑，推动了全球新能源产业的共同繁荣。

同时，中国新能源企业在全球范围内的布局与扩张也加速了全球新能源产业链的全球化进程，促进了国际资源的优化配置与共享。这种产业链的优化和重构不仅提高了全球新能源产业的竞争力，还为全球经济的可持续发展提供了有力支撑。

（三）中国新能源产品推动世界技术进步，促进国际创新合作

在全球科技竞争与可持续发展的双重驱动下，中国新能源产品以其独特的创新能力和市场影响力，不仅满足了全球对清洁能源的迫切需求，更在推动世界技术进步和促进国际创新合作方面发挥了重要作用。

中国新能源产业在几十年间实现了从无到有、从小到大的飞跃式发展，其背后离不开持续的技术创新。从光伏技术的光电转换效率提升到风电设备的智能化运维，再到新能源汽车的电池技术突破和智能驾驶系统的研发，中国新能源产品不断刷新行业技术标准。这些技术创新不仅提升了中国新能源产品的国际竞争力，更为全球新能源领域的技术进步树立了标杆，引领全球新能源产业的发展方向。

中国新能源产业投资具有显著的技术溢出效应（陈培如、冼国明，2020），随着中国新能源产品在全球市场的广泛应用，越来越多的国际企业和研究机构开始关注并参与到中国新能源产业的技术交流与合作中来。这种交流与合作不仅促进了技术知识的传播与共享，还为全球创新提供了新的灵感与合作机会。例如，中国新能源企业与国际科研机构合作，共同攻克技术难题；同时，中国也积极引进国外先进技术和管理经验，加速自身技术升级和产业转型。这种双向交流与合作

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模式不仅推动了世界新能源技术的进步，也促进了国际创新合作的发展。

三、中国新能源产业发展演变特征

（一）逐渐走向成熟发展阶段

在全球能源低碳转型的浪潮中，中国新能源产业遵循产业发展的一般规律，历经了萌芽期、快速成长期，目前已进入成熟发展阶段。

萌芽期（1950s~1999年）：这一阶段，中国面对能源短缺挑战，开始探索小水电、沼气池等新能源技术，但受限于技术不成熟、市场认知度低，以及供应链不完善，新能源产业发展缓慢且分散，新能源技术处于初步研发阶段，主要应用于小规模、地方性项目。

快速成长阶段（2010~2017年）：随着全球对低碳经济的重视，以及中国碳减排承诺的提出，新能源产业迎来了高速发展。技术进步与政策扶持双重推动了太阳能光伏、风电等产业的装机容量快速增长，动力电池与新能源汽车市场亦迅速扩大。如图1所示，我国风电装机容量从2010年的2958万千瓦上升到2017年的16325万千瓦，增长了451.89%；光电装机容量从2010年的几乎为0上升到2017年的12942万千瓦。我国动力电池装机容量从2013年的0.8吉瓦时（GWh）上升到2017年的36.24吉瓦时，新能源汽车销售量从2014年的7.5万辆上升到2017年的77.7万辆。此阶段，产业规模迅速扩张，市场竞争激烈，企业通过技术创新与效率提升建立了竞争优势，行业壁垒逐渐形成，市场集中度提高。

成熟发展阶段（2018年至今）：进入成熟期后，新能源产业增速放缓，市场趋于饱和，竞争焦点转向效率与盈利能力的提升。在“双碳”目标引领下，中国新能源汽车产业的表现尤为突出，政策支持力度不断加大，智能化、网联化发展趋势显著，充电与储能基础设施建设也在加速推进。如图1所示，风电装机容量从2018年的18427万千瓦上升到2023年的36564万千瓦，光电装机容量从2018年的17433万千瓦上升到2023年的39268万千瓦。我国动力电池装机容量从2018年的56.89GWh上升到2023年的387.7GWh，新能源汽车销量从2018年的125.6万辆上升到2023年的900万辆。宁德时代、比亚迪等企业推出了多项创新技术，显著增强了国际竞争力。尽管技术难题如续航里程、电池稳定性等仍需攻克，但企业持续加大研发投入，市场集中度进一步提升，预示着该阶段具有了强劲发展潜力。

（二）不断强化市场机制

在产业初期和快速发展阶段，政府通过政策扶持、法律制度保障以及解决产业面临的关键问题，奠定了新能源产业的坚实基础。比如，政府通过制定一系列规划（如2000年《新能源和可再生

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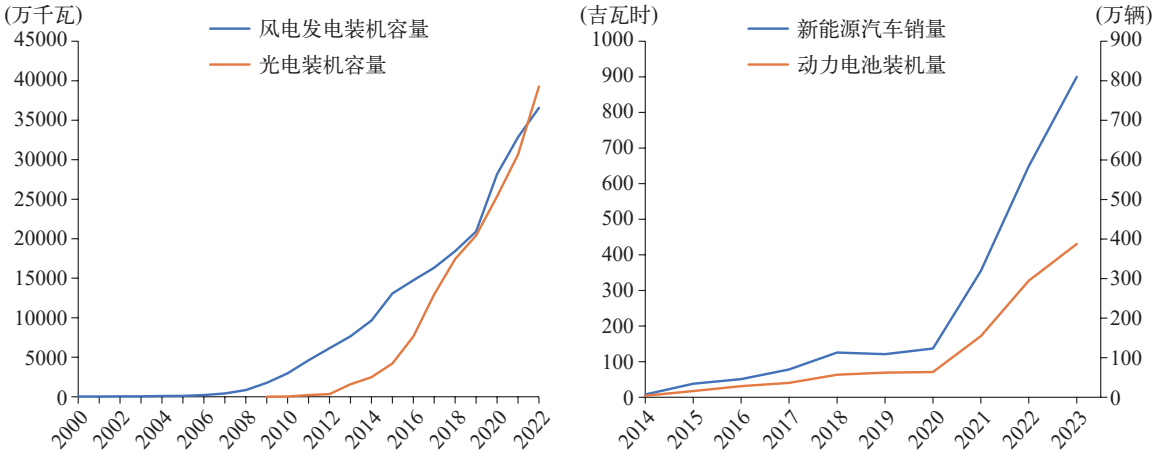

图1:中国新能源产品历年变化情况

数据来源:中国历年统计年鉴,作者整理。

能源产业发展规划》、2006年《可再生能源中长期发展规划》)和决定(如2010年《关于加快培育和发展战略性新兴产业的决定》),明确了产业发展方向,加大了对重点行业的支持力度,建立了促进产业发展的服务体系。政府不断完善新能源产业发展的法律制度,通过《清洁生产促进法》《可再生能源法》及其修正案等法律法规,保障新能源发电并网、全额保障性收购和设立发展基金,有效促进了新能源产业的发展。

通过电力市场化改革、绿色电力证书交易制度、可再生能源电力配额制等措施,中国政府积极推动新能源电力参与市场竞争。电力市场化改革是新能源市场化运行的基础,自2002年《电力体制改革方案》批准以来,中国电力工业逐步迈向市场化。特别是2015年《关于进一步深化电力体制改革的若干意见》的出台,明确了"三放开、一独立、三强化"的改革路径。近年来,国家加快了构建多层次统一电力市场体系的步伐,并积极推动国家电力市场的建设。一系列指导意见和通知的出台进一步推动了电力市场的统一与开放,为新能源电力提供了更加广阔的市场空间和发展机遇。在此基础上,2017年,国家发展改革委、财政部、能源局三部门颁布《关于试行可再生能源绿色电力证书核发及自愿认购交易制度的通知》,提出从2017年7月1日起正式开展绿色证书的认购制度,逐步拓宽了新能源补贴的来源渠道。2023年和2024年分别出台的《关于做好可再生能源绿色电力证书全覆盖工作 促进可再生能源电力消费的通知》《关于加强绿色电力证书与节能降碳政策衔接大力促进非化石能源消费的通知》进一步完善并支持绿色电力证书交易制度。这种绿证加配额制的市场化交易体系为新能源电力消纳提供有力保障,清洁能源参与市场交易规模持续增加,2021年全国通过市场化方式消纳清洁能源7215亿千瓦时(刘朋,2022)。

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（三）不断增强自我发展能力

在新能源产业发展初期，面临着成本高、技术不成熟、市场竞争力弱等诸多挑战。因此，政府通过财政补贴、税收优惠等政策大力支持新能源产业。无论是欧盟的可再生赋能计划，还是美国的《2009年美国复苏与再投资法案》，都体现了政府对新能源产业的大力扶持。同样，我国自2005年开始实施《中华人民共和国可再生能源法》以来，通过电价补贴和配额交易等政策手段，有效降低了新能源发电成本，提高了市场竞争力。这些政策不仅促进了新能源产业的快速发展，还为其后续的技术进步和成本降低奠定了基础。

随着技术的不断进步和规模效应的显现，新能源产业的成本迅速下降。以光伏发电为例，技术进步提高了光伏组件的效率，生产成本大幅降低。同时，随着产业链的不断完善和市场机制的逐步形成，光伏发电项目的投资回报率不断提升，吸引了更多社会资本的进入。2018年，国家发展改革委、财政部、能源局联合发文，完善光伏发电电价机制，降低补贴强度，鼓励各地出台光伏产业政策。随着市场化配置的成熟和各地政策的完善，2021年1月1日起，中央财政退出补贴，集中式光伏发电站上网电价按照当地燃煤发电基准价执行。2022年起，无论是集中式还是工商业分布式光伏项目，都不再获得中央财政补贴。

随着电力市场改革的深入和光伏发电成本的快速下降，中国光伏发电已经实现平价甚至低价上网。这说明中国新能源产业具有较强的自我成长能力，能够快速适应市场形势的变化，提升市场竞争力。

四、中国新能源产业发展的竞争优势

新能源产业是我国战略性新兴产业的重要组成部分，也是我国实现能源绿色转型的重要支撑。经过近十年的发展，我国已成为全球新能源产业的领跑者。能源“新三样”产品之所以在全球消费者中广受欢迎，主要是由于我国产品价格低、科技含量高，在国际市场上具有较强竞争优势。

（一）矿产资源丰富：奠定新能源产业发展基础

我国新能源产业快速发展得益于丰富的矿产资源储备与优越的地质成矿条件，这些资源为“新三样”产品的生产提供了廉价的原材料，极大地降低了生产成本，为新能源产业链的上下游提供了坚实的物质保障。

一是多晶硅资源。多晶硅是光伏产业的核心材料，我国是全球最大的多晶硅生产国，产能与产量均处于全球领先地位。近年来，随着光伏技术的进步和全球能源转型的加速，我国多晶硅产

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量快速增长，2023年达到了约147.2万吨，同比增长71.8%[②]。新疆、内蒙古、四川等地凭借低廉的电力成本和优越的生产条件，成为多晶硅生产的主要基地，进一步巩固了我国在全球光伏产业链的核心地位。

二是稀土资源。在新能源汽车产业中，稀土是制造高性能电机、电池和催化剂等关键部件的必需材料。我国不仅拥有全球最大稀土储量，约4400万吨，占全球总储量的44%，更重要的是，我国在稀土产业的开采、提炼和应用等方面拥有完整的产业链，掌握了全球大部分稀土资源的加工技术和供应能力[③]。

三是石英与石墨资源。石英是光伏和电子等多个行业的基础原料，我国已探明的高品位石英储量超过140亿吨，能够为相关产业提供稳定的原料供应。石墨资源方面，我国以7800万吨的天然石墨储量位居世界首位，占全球储量的27.86%[④]。石墨在锂离子电池和石墨烯新材料等领域具有广泛应用前景，丰富的储量和优质的矿石品质为我国新能源及新材料产业的快速发展奠定了坚实基础。

四是锂矿资源。作为新能源汽车和储能技术的关键原材料，锂矿资源的丰富性对我国新能源产业至关重要。世界锂矿主要分布在南美锂三角（玻利维亚、智利、阿根廷），其中智利第一，占比35.78%。我国锂矿储量全球第四，储量相对丰富[⑤]。分布较为广泛，如青海南部的盐湖和四川的矿床。相对丰富的锂矿资源，为我国新能源汽车产业的快速发展提供了强有力的支撑。

（二）超大规模市场优势：发挥新能源产业规模效应

我国作为世界第二大经济体，拥有超大规模的市场优势，这一独特条件为“新三样”的快速发展创造了广阔的空间和无限的潜力。这一市场优势不仅体现在庞大的消费群体和多样化的消费需求上，更在于其能够激发技术创新、促进产业升级，并推动形成具有国际竞争力的产业集群。

第一，超大规模市场为新技术、新产品的应用与推广提供了肥沃的土壤。由于人口基数大、消费层次丰富，我国市场对新技术的接受度较高，对新产品的需求量也较大。这促使企业不断投入研发，推出符合市场需求的高端化、智能化、绿色化产品。“新三样”作为先进制造业的代表，正是凭借其技术创新和产品优势，迅速崛起，赢得了消费者的认可。

第二，规模经济效应显著，助力企业降低成本、提升竞争力。“新三样”产业在初期需要较大的固定成本和创新成本，而中国的超大市场规模使企业能够通过大规模生产和销售摊薄成本，进而

[②] 新浪财经：光伏的重要原料——多晶硅的供需格局，https://finance.sina.com.cn/money/future/wemedia/2024-08-26/doc-inckxptr5157796.shtml。

[③] 腾讯网：中美俄稀土储量对比：我国稀土的优势地位究竟有多大？ https://news.qq.com/rain/a/20240920A031BJ00。

[④] 观研报告网：我国天然石墨行业发展现状：准入门槛提高 产量整体保持增长但出口量下滑，https://www.chinabaogao.com/market/202409/728169.html。

[⑤] 华经情报网：2023年全球及中国锂行业发展现状，国内锂资源以盐湖为主，https://www.huaon.com/channel/trend/947413.html。

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实现盈利(周潇枭,2024)。这种成本优势不仅帮助企业在国内市场上占据领先地位,还为其开拓国际市场、提升竞争力提供了有力支持。此外,规模经济还促进了产业链完善和优化,形成了上下游协同发展的良好生态。

第三,超大规模市场能够容纳多条技术路线的竞争和成长。在"新三样"领域,技术创新是推动产业发展的关键动力。我国市场规模足够大,能够容纳多种技术路线并存竞争。以锂电池为例,市场上既有三元锂电池这样的高能量密度产品,也有磷酸铁锂电池这样的高性价比选择。这种多元化的竞争格局不仅促进了技术创新和产业升级,还为消费者提供了多样化的选择。

第四,超大规模市场对全球产业链具有强大的吸引力和影响力。随着我国"新三样"产业的快速发展和市场规模的不断扩大,越来越多的国际企业将目光投向中国市场,寻求合作机会。这不仅加深了我国与国际市场的融合与合作,还提升了我国在全球产业链中的地位和影响力。

(三)自然地理环境适合:提供新能源产业应用场景

新能源产业的发展高度依赖于特定的自然地理环境,这对资源的利用效率与环境的适应性提出了很高要求。在这方面,我国具备独特的优势,为新能源产业的蓬勃发展奠定了坚实的基础。

首先,我国地域辽阔,横跨多个气候带,多样性地理环境为不同类型的新能源项目提供了丰富的应用场景。光伏发电作为新能源的重要组成部分,对光照条件有极高的要求。我国大部分地区,尤其是中西部地区,年日照时数长,太阳辐射强,全国超过2/3的地区年辐射量达到或超过5000兆焦每平方米,为光伏发电的广泛应用提供了理想的自然条件。充足的光照资源不仅降低了光伏发电的成本,还提高了经济效益,使光伏发电在我国新能源产业中占据了重要地位。

其次,我国风能资源丰富,且分布广泛。我国"三北"地区(东北、华北北部和西北)风能资源丰富,这些地区地势平坦,风力强劲且稳定,非常适合大规模风电场的建设。此外,我国沿海地区也拥有丰富的风能资源,得益于海洋性气候和地形特点,沿海地区的风力资源具有较大的开发潜力。丰富的风能资源不仅为我国风电产业的发展提供了有力支撑,也有助于推动能源结构的多元化和低碳化转型。

无论是光伏发电、风力发电,还是其他类型的新能源项目,都能在我国找到适宜的发展环境和广阔的应用空间。这些自然优势不仅为我国新能源产业的快速发展提供了有力保障,也为全球新能源产业的合作与交流提供了新的机遇和平台。

(四)人力资本优势:赋能新能源产业智力支持

随着全球经济格局的深刻变化与产业结构的转型升级,我国的经济发展逐步从依赖传统"老三样"(服装、家电、家具)的出口模式,转向以新能源汽车、光伏产品、锂电池等"新三样"为代表的

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高质量发展阶段。在这一转型过程中，高素质的人才优势成为推动“新三样”蓬勃发展的核心动力与智力支持。

一是高端研发人才的引领作用。“新三样”作为高新技术产业的代表，其核心竞争力在于技术创新与研发能力。近年来，我国加大了对高等教育与科研机构的投入，培养了大量具有国际视野、创新精神和专业能力的研发人才。这些高端人才在新能源技术、光伏材料科学、电池管理系统等关键领域取得了突破性进展，为“新三样”产业提供了持续的创新动力，推动了产品性能的升级和生产成本的有效控制。

二是技能人才的广泛参与。除了高端研发人才外，掌握先进生产技术和操作技能的基础劳动力同样不可或缺。我国的技能人才队伍规模庞大，且技能水平不断提升，特别是在智能制造、自动化生产线等领域，技能人才的广泛应用显著提高了生产效率，保证了产品质量的稳定性。同时，通过职业技能培训和再教育项目，我国实现了劳动力技能的更新与升级，为“新三样”产业的快速发展提供了坚实的人力基础。

三是教育体系的优化与支撑。我国教育体系的持续优化为“新三样”发展提供了长远的人才保障。从基础教育到高等教育，再到职业教育与继续教育，形成了一个覆盖全面、结构合理的教育体系。特别是近年来，国家大力推动职业教育与产业发展深度融合，鼓励校企合作、工学结合，为“新三样”及相关产业培养了大量符合市场需求的高素质技能型人才。

四是政策环境的支持与激励。政府通过出台一系列的人才政策，如人才引进计划、科研项目资助、创新激励措施等，进一步激发了人才的创新活力与创业热情。同时，优化营商环境，简化审批流程，为“新三样”企业提供更加便捷高效的服务，吸引了更多国内外优秀人才。

（五）科技创新驱动：提升新能源产品科技含量

“新三样”领域不断吸纳最新科技成果，推动产品能效提升和性能稳定。科技含量高是中国能源“新三样”产品在全球畅销的关键因素之一。我国在新能源产业方面展现出了显著的技术优势，主要体现在以下几个关键领域。

一是电池技术。我国在新能源汽车电池技术方面取得了重大突破，宁德时代等企业在电池能量密度、安全性和循环寿命等方面均达到了国际领先水平。此外，固态电池等新型储能技术的研发也在加速推进，未来有望进一步提升新能源汽车的性能。

二是整车技术。以比亚迪、特斯拉（上海超级工厂）等为代表的新能源汽车制造商，在整车设计、制造和智能化等领域具有显著优势，推动了新能源汽车市场的快速发展。

三是光伏技术。我国在光伏产业方面拥有完整的产业链和先进的技术水平。如图2所示，2013

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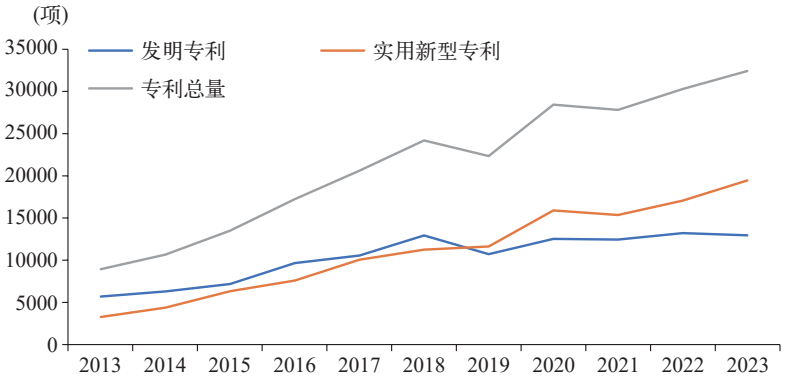

图2:2013~2023年光伏太阳能专利申请数量增长量

数据来源:中国国家专利数据库,作者整理。

年至2023年,太阳能光伏相关专利数量快速增长,其中,发明专利总量从8907件到32443件,十年间增长近4倍,远超欧美等其他国家。隆基绿能等企业在提升电池转换效率方面取得了显著成果,晶硅单结电池和晶硅-钙钛矿叠层电池的效率均达到了世界领先水平。

四是光伏耦合技术。我国在光伏耦合技术方面也取得了重要进展,通过将光伏系统与其他能源系统的深度融合,提高了能源利用率和系统的稳定性。

(六)产业链供应链完善:提高新能源产业生产效率

在全球经济一体化的背景下,产业链供应链的完善程度已成为衡量一个国家制造业竞争力的重要标准。我国是全球唯一拥有联合国产业分类中全部工业门类的国家,220多种工业产品产量居世界首位,连续13年保持制造业规模世界第一。完备的工业体系保障了新能源产品生产基本实现自主。例如,比亚迪汽车电池自主研发、生产,电机、电控系统及雷达等零部件均为自主生产,而特斯拉上海工厂大部分为整车总装。完整的产业链供应链能够实现原材料、零部件的集中采购与优化配置,降低采购成本,提高生产效率。同时,通过规模化生产和技术创新,进一步降低新能源产品的生产成本,提高市场竞争力:

一是全产业链优势凸显。我国拥有完整的产业链体系,从原材料供应到终端产品服务,覆盖了研发设计、生产制造、市场营销和售后服务的每个环节。这种全产业链优势不仅降低了企业的运营成本,提高了生产效率,还增强了产业链上下游企业之间的协同效应,为快速响应市场需求提供了有力保障。尤其在新能源汽车领域,我国已形成了涵盖核心零部件、整车制造和服务在内的完整产业链,构建了强大的产业生态。

二是产业集群效应显著。为促进产业链供应链的高效协同,我国积极推动产业集群式发展,

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通过区域合作与资源整合，打造了一批具有国际竞争力的产业集群。以长三角地区为例，新能源汽车产业形成了高度集聚的发展态势。安徽合肥作为新能源汽车产业的重要基地，汇聚了多家整车制造企业。安徽的整车组装与上海的芯片软件研发、江苏的动力电池制造以及浙江的车身一体化压铸模具形成强大的供应保障体系，共同打造新能源企业“4小时产业圈”。区域间的协同合作，不仅促进了技术、人才、资金等要素的自由流动，还加速了产业链上下游企业的深度融合，构建了高效协同的供应链体系。

三是创新驱动产业升级。在完善产业链供应链的过程中，我国始终将创新驱动作为核心动力。通过加大研发投入，推动技术创新和产业升级，不断提升产业链的核心竞争力。在新能源汽车领域，我国企业在动力电池、电机电控等关键技术上取得了重大突破，不仅打破了国外的技术垄断，还实现了对国际市场的反向输出。同时，智能网联、自动驾驶等前沿技术的快速发展，也为新能源汽车产业注入了新的活力，推动了产业链的进一步升级。

四是面向全球市场的供应链韧性。面对复杂多变的国际环境，我国产业链供应链展现出了强大的韧性。通过多元化布局和全球化合作，我国企业在确保供应链稳定的同时，也积极开拓国际市场，提升全球市场份额。特别是在新能源汽车领域，我国企业凭借先进的技术、优质的产品和完善的售后服务体系，赢得了全球消费者的广泛认可，为全球新能源汽车产业的可持续发展贡献了中国力量。

（七）政府引导合理布局：促进新能源产业有序发展

为了促进“新三样”产品合理有序发展，中国政府通过一系列精准施策、科学规划与合理布局，旨在构建一个充满活力且健康有序的市场环境，推动新能源产业实现高质量增长。

一是明确战略定位，制定长远规划。国家层面出台了一系列战略规划和政策文件，如《新能源汽车产业发展规划（2021~2035年）》《国务院关于促进光伏产业健康发展的若干意见》等，为“新三样”产业的发展提供了明确的方向和有力的支持，这些文件设定了市场规模、技术创新、产业链完善、国际竞争力提升等关键指标。针对各细分领域，制定了详细的产业发展规划，明确了发展路径、重点任务和政策措施，确保产业发展有章可循、有序推进。

二是顺应能源转型，贡献中国方案。在全球能源结构深刻变革的大背景下，政府鼓励中国新能源企业通过加强与国际先进企业的技术交流与合作，共同推动关键技术突破与升级。支持中国新能源企业走出国门，将物美价廉的新能源产品推向全球市场，不仅为世界各国提供了清洁、高效的能源解决方案，也促进了当地经济的可持续发展和民生改善。

三是优化产业布局，促进区域协同。根据各地的资源禀赋、产业基础和市场需求，引导“新三

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样”产业在不同地区形成差异化、特色化发展格局，避免同质化竞争。支持建设一批国家级、省级“新三样”产业集群，通过集聚效应促进产业链上下游企业紧密合作，提升整体竞争力。加强区域间政策协调、信息共享和资源整合，推动形成优势互补、协同发展的产业生态体系。

四是强化政策引导，激发市场活力。在产业发展初期，政府加大对“新三样”产业的财政投入，通过补贴、奖励、贷款贴息等方式，降低企业研发成本和经营风险。对符合条件的“新三样”企业给予税收减免、研发费用加计扣除等优惠政策，鼓励企业加大研发投入和技术创新。当新能源产业逐渐成熟后，政府及时建立补贴退坡机制，依靠市场力量优化产业布局，实现优胜劣汰，提升企业竞争力。

五、中国新能源产业发展的政策建议

中国新能源汽车、锂电和光伏等“新三样”领域的快速崛起为我国经济高质量发展注入了强劲动力。这些领域的创新突破，不仅加快了产业升级，增强了产业竞争力，更通过提供清洁、高效的能源解决方案，有效减少了温室气体排放，对应对气候变化和推动绿色低碳转型具有不可替代的作用。然而，在当前国际能源市场波动的情况下，我国新能源产业面临国际上的不当言论、“大院小墙”的技术封锁及“脱钩断链”的市场围堵等多重挑战。我国政府需要积极应对，采取措施加强政策指引、促进技术突破，依靠市场机制补链强链，促进新能源产业高质量发展。

（一）加强政策指引，优化产业布局和资源配置

面对新能源产业的结构性产能过剩问题，中国政府需从顶层设计出发，强化政策引导，优化产业布局，提升资源配置效率，推动新能源产业高质量发展。

一是明确产业发展规划与政策体系。政府应基于全局视角，制定新能源产业的中长期发展规划，明确发展目标、阶段性任务及关键保障措施。规划需注重前瞻性、科学性和可操作性，为产业发展提供清晰的方向指引和稳定的政策预期。在新能源项目与储能项目的协同发展中，政府应通过政策引导和市场机制，鼓励“风光储”一体化项目的建设。借鉴成功案例，如中国核工业集团有限公司的玉门“光热+”项目，推动新能源与储能技术的深度融合，提升能源系统的整体效能和稳定性。

二是强化金融支持与绿色金融创新。政府应通过税收优惠、财政补贴、融资担保等手段加强对新能源产业的金融支持。鼓励金融机构创新“新能源+绿色金融”融资模式，综合运用股权、债权、资产证券化等金融工具，为绿色低碳项目提供灵活、多元化的融资解决方案。针对新能源企业资金需求大、市场风险高、固定资产少、回报周期长的特点，政府应协调金融机构优化信贷政策，

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降低企业融资成本，提高融资效率，确保新能源项目获得充足的资金支持。

三是建立产业信息预警与引导机制。政府应建立全面的产业信息监测与发布机制，利用大数据、云计算等现代信息技术手段，全面收集新能源产业相关数据，实时掌握产业发展趋势和市场动态。通过官方网站、行业媒体、社交媒体等渠道，定期发布产业分析报告、市场预测、政策解读等信息，确保企业能够及时获取准确的市场信息。同时，对重点行业、重点企业的产能利用情况进行跟踪监测，评估产能过剩风险，及时发布预警信息，引导企业合理投资、理性发展。

四是政策引导与产能调控。针对产能过剩风险较高的行业和企业，政府应及时出台相关政策，如调整产业政策、加强环保监管等，防止企业恶性竞争。同时，鼓励企业通过技术创新、转型升级等方式提高产品附加值和市场竞争力，实现可持续发展。

（二）加强关键技术突破，提升新能源产品技术含量

在创新驱动发展战略的引领下，中国新能源产业正步入智能化、绿色化发展的新纪元，展现出蓬勃生机与广阔前景。为持续推动新能源产业与技术的双重飞跃，实现关键技术的重大突破与全面升级，需采取一系列综合策略，包括但不限于加大研发投入、强化人才培养及加强知识产权保护等方面。

一是聚焦核心技术，强化创新攻关。集中优质资源，针对新能源产业智能制造中的关键核心技术和零部件的薄弱环节（如高效电池技术、智能电网技术、先进储能技术等），开展合力攻关。设立专项基金，增加对关键领域和核心技术研发项目的财政支持与资金投入，确保研发活动有足够的资源保障。充分利用中国完备的产业体系、庞大的内需市场以及强大的国家动员与组织能力，加速科技成果向现实生产力转化，构建自主可控、安全可靠的供应链体系。

二是深化产学研合作，培育创新生态。加强政府、企业、高校及科研机构之间的紧密合作，建立产学研深度融合的创新网络，促进技术、人才、资金等创新要素的流动与共享。实施更加开放的人才政策，吸引国内外顶尖科研人才投身新能源领域。同时，建立完善的人才培养体系，注重培养跨学科、复合型创新人才，为新能源产业发展提供持续的人才支持。通过建立健全激励机制，如科研成果奖励、股权激励等，激发科研人员的创新积极性和创造力，形成持续的创新动力。

三是加强知识产权保护，提升国际竞争力。加大对新能源领域知识产权的保护力度，建立健全知识产权快速维权、协同保护及海外纠纷应对机制，为创新成果提供坚实的法律保障。建立完善的知识产权转化机制，促进创新成果向现实生产力转化，提高知识产权的经济效益和社会效益。积极参与国内外新能源领域相关标准的制定与修订工作，推动中国标准国际化，提升中国新能源产品在国际市场上的竞争力和话语权。

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（三）依靠市场机制，促进新能源产业健康发展

在新能源产业发展初期，由于市场和技术不成熟，生产成本较高，因此各国政府通常会通过补贴政策推动产业规模快速扩张。然而，这类补贴也容易导致企业产生“补贴依赖症”，削弱其市场竞争力。随着新能源产业逐渐成熟和技术进步，补贴政策应当逐步退坡，以促使企业依靠技术创新和市场机制实现可持续发展。建立新产业发展的市场机制是推动新能源产业高质量发展的关键。

一是加快推进电价市场改革进程。深化电力体制改革，建立健全能够反映市场供求变化、资源稀缺性和环境治理成本的电价形成机制。通过竞争性市场决定电价，促进发电侧和售电侧形成有效竞争，激发市场活力。鼓励和支持可再生能源发电参与市场竞争，通过实施绿色证书交易、电价补贴优惠等政策，促进清洁能源发展。同时，探索建立反映环境成本的电价机制（如碳定价机制），将碳排放成本纳入电价体系，引导电力生产和消费向绿色低碳转型。

二是推动绿色电力交易机制建设。允许新能源发电企业通过市场直接销售绿色电力，增强其市场竞争力。完善绿色电力证书（绿证）核发和交易制度，将绿证作为新能源电力消费量的重要凭证，促进绿电消费和绿色证书交易市场的健康发展。建立新能源电力配额制，要求各省级行政区域承担一定的新能源电力消纳责任，并通过碳市场实现环境价值的流转和补偿。丰富绿色电力市场交易品种和方式，如引入期权、期货等金融衍生品，提高市场流动性和风险管理能力。

三是不断丰富绿色电力市场交易品种和方式。通过引入期权、期货等金融衍生品，提高市场的流动性和风险管理能力。建立健全新能源市场的监管体系，加强对市场主体的监管和评估，确保市场公平、公正和透明。加强各部门之间的政策协调和沟通，形成合力推动新能源产业发展。

（四）加强补链强链，提升新能源产业链韧性

在当前全球贸易环境复杂多变的背景下，特别是以美国为首的部分国家通过提高可再生能源产品关税和发起反补贴调查等措施，对我国新能源产业构成围堵与挑战。面对这一形势，加强我国新能源产业链的补链强链工作，提升产业抗风险能力尤为重要。

一是优化产业链布局，提升自主可控能力。首先，应深入分析新能源产业链的薄弱环节，特别是核心零部件和关键材料领域。通过加大研发投入，支持企业技术创新和产业升级，逐步缩小与西方国家在关键技术上的差距。同时，鼓励产业链上下游企业加强协同合作，形成紧密的产业生态，提升整体竞争力。在关键矿物开采加工、关键材料和零部件生产制造等环节，推动形成一批具有国际竞争力的龙头企业，增强产业链的自主可控能力。

二是拓展国际合作，构建多元化供应链。面对地缘政治风险的不确定性，加强国际合作与交

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流是降低供应链风险的有效途径。应积极推动与“一带一路”沿线国家及其他友好国家的产能合作，尤其在新能源领域开展深度合作。通过简化项目审批、提供金融政策支持等措施，鼓励具备实力的新能源企业“走出去”，参与国际市场竞争，拓展海外市场。同时，积极引进国外先进技术和管理经验，提升我国新能源产业的国际化水平。

三是调整进口政策，鼓励高质量产品进口。针对部分关键零部件和原材料依赖进口的现状，适时调整进口政策，通过调整税率和进口国范围等手段，鼓励更高能级、更高质量的产品进口。这不仅可以满足国内市场的需求，提升产品性能和质量，还能促进国内企业与国外先进企业的技术交流与合作，推动产业升级和高质量发展。

四是强化循环再造技术，构建韧性供应链。循环再造是提升资源利用效率、减少环境污染的重要途径。应加大对锂电循环等关键技术的研发投入，支持国内企业构建全球废旧电池回收网络。通过引进海外废旧电池资源，进行循环再造后融入国内产业链，既可以增加再生原料比例，降低对原生资源的依赖，还能提升产业链的韧性和可持续性。同时，鼓励企业出口高附加值产品，拓宽国际市场渠道，提升国际竞争力。

综上所述，加强补链强链工作、提升新能源产业抗风险能力需要从多个方面入手。通过优化产业链布局、拓展国际合作、调整进口政策以及强化循环再造技术等措施的综合施策，可以构建更加安全、稳定、高效的新能源产业链体系，为我国新能源产业的持续健康发展提供有力保障。

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China's New Energy Industry: Key Characteristics and Competitive Advantages

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Abstract: *In recent years, China's burgeoning exports of "new three" products have led some Western media outlets and politicians to falsely claim that China is experiencing overcapacity in the new energy sector. These entities and individuals have advocated for countervailing investigations into China's new energy products, increased tariffs, and other anti-free trade measures. To address such unfounded criticisms, we have outlined three major contributions of China's new energy industry to the world. Building upon a summary of the three evolving characteristics and seven competitive strengths of the industry, we present policy recommendations for the high-quality development of China's new energy industry. Our findings provide a factual basis to refute the unfounded claims of certain Western countries.*

Keywords: *New energy industry, development characteristics, competitive advantages, carbon emissions*
JEL Classification Codes: Q43, Q47, O13
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1. Introduction

In recent years, China's new energy products have gained significant global traction. China has maintained its leading position in photovoltaic component manufacturing for 16 consecutive years, accounting for over 80% of global output and capacity in polycrystalline silicon, silicon wafers, and solar cells (Zhang, 2024). China's new energy vehicle (NEV) industry has rapidly evolved from a follower to a global leader. In 2023, Chinese NEVs captured a global market share of 65%-68%, and this figure is projected to exceed 70% by 2025. According to General Customs Administration data, China's combined exports of NEVs, lithium-ion batteries, and photovoltaic products[1] surpassed one trillion yuan for the first time in 2023 (Lin, 2024).

However, some Western media outlets and politicians have frequently invoked the "overcapacity" argument to impede China's NEV development. US Treasury Secretary Janet Yellen repeatedly cited "overcapacity" in China's new energy industry. In May 2024, the US government significantly increased tariffs on Chinese electric vehicles(EVs), photovoltaic products, and lithium-ion batteries to 100%, 50%, and 25%, respectively, on the basis of the existing Section 301 tariffs. Despite the absence of an industry

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[1] In this paper, new energy vehicles mainly refers to electric vehicles (EVs), photovoltaic products mainly refers to solar panels.

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petition, the European Commission (EC) initiated a countervailing investigation into Chinese EVs. The EC meticulously documented information about each EV model sold in Europe to justify potential penalties. Additionally, the EC launched countervailing investigations into Chinese photovoltaic enterprises under the *Foreign Subsidies Regulation* (FSR).

Undeniably, these accusations are unfounded and inconsistent with factual evidence. The practices of countervailing investigations and tariff increases contravene the principles of free trade and could hinder global energy transition efforts. Such accusations stem from a misunderstanding of China's new energy industry's global contributions, development trajectory, and product competitiveness. Previous academic research has focused on the development characteristics of China's new energy industry (Chen et al., 2022; Hu, 2022; Li, 2024), competitive strengths (Han, 2024; Li, 2023; Liu, 2024; Yang and Song, 2024), and strategies to address trade barriers (Guo and Li, 2024; Duan, 2015). However, there is a dearth of systematic research on the competitive strengths of China's "new three" exports, limiting effective responses to concerns raised by certain countries regarding China's new energy industrial competitiveness. This paper aims to address this gap by identifying China's new energy industry's threefold global contributions and seven competitive advantages. Finally, we propose strategic recommendations for the high-quality development of China's new energy industry.

2. China's Role in Accelerating Global Energy Transition

New energy, with its widespread availability, high potential, and low-carbon, environmentally friendly characteristics, has become a crucial solution for countries addressing climate change. To conserve energy, reduce emissions, and achieve carbon peak and neutrality goals, the Chinese government has made substantial investments in the new energy industry, particularly in NEVs, lithium-ion batteries, and photovoltaic power. This strategic approach is vital for both China and the global community.

2.1 China's New Energy Industry: Driving Global Carbon Reduction

As global climate change and environmental protection become increasingly pressing international concerns, all nations face the significant challenge of mitigating climate change by reducing CO_2 emissions (Fan et al., 2024). China, as the world's largest carbon emitter, faces considerable pressure to ensure its economic sustainability due to its coal-dominated energy mix. In response, China is committed to accelerating energy transition and developing the new energy industry as a key strategy to fulfill its international obligations and reduce carbon emissions.

Second, China's carbon emissions account for one-third of global total. Its development of new energy to replace coal and other fossil fuels will directly help reduce the total global carbon emissions. In 2022, China's substantial increase in renewable energy-based power generation reduced CO_2 emissions by 2.26 billion tons (Ye, 2024), making a significant contribution to global carbon emission reduction efforts.

Third, China's "new three" exports have contributed to global energy conservation and reduced carbon emissions in other countries. China's exports of wind and photovoltaic products are estimated to have helped other countries reduce CO2 emissions by 573 million tons, accounting for 41% of global emissions reductions from renewable energy sources (Ye, 2024).

Consequently, China is the largest contributor to global renewable energy development (Dong, 2024). China's new energy industry has not only reduced carbon emissions for itself, but also indirectly

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reduced carbon emissions in other countries, providing critical support for meeting global temperature control targets.

2.2 China's Trade in New Energy Products: Driving Global Economic Growth and Industrial Chain Collaboration

First, China's new energy industry is driving global trade by meeting the surging demand for clean energy solutions. China's leadership in NEVs, lithium-ion batteries, and solar cells has provided countries worldwide with a wealth of clean energy options. For instance, Chinese solar cell manufacturers have established numerous factories in Southeast Asia, Africa, and other regions, not only meeting local energy needs but also generating jobs and stimulating local economic development. Similarly, Chinese electric vehicle (EV) manufacturers have set up factories and R&D centers in Europe, Southeast Asia, and elsewhere, fostering partnerships with local companies and accelerating global EV industry development. China's "new three" energy products have emerged as a new engine of global economic growth due to their high value-added, rapid growth, and extensive market potential. The export of new energy products not only promotes the prosperity of international trade but also strengthens economic cooperation. It also injects new vitality into global integration and accelerates the recovery and growth of the world economy.

Second, China's new energy trade fosters global industrial chain cooperation. China has forged strong partnerships with numerous countries and regions to advance new energy development. This cooperation extends beyond goods trade to encompass technology R&D, industrial chain consolidation, and market exploration. By collaborating closely with international partners, Chinese new energy enterprises have accelerated their integration into global industrial chains, enhancing their international competitiveness. Such cooperation also significantly supports the coordinated development of the global new energy industry, driving overall industry growth.

The global expansion of China's new energy enterprises has accelerated the globalization of the new energy industry, leading to the optimal allocation and sharing of global resources. Such industrial optimization and restructuring has enhanced the competitiveness of the global new energy industry, ultimately contributing to global economic sustainability.

2.3 China's New Energy Products: Catalysts for Global Technological Leaps and Collaborative Innovation

Fueled by global technological competition and sustainable development goals, China's innovative new energy products have not only met the urgent global demand for clean energy but have also played a pivotal role in advancing global technological progress and fostering international innovation cooperation.

Thanks to relentless technological innovation, China's new energy sector has rapidly transformed from obscurity to prosperity in a few decades. From improving the electro-optical efficiency of photovoltaic cells to advancing the intelligent operation and maintenance of wind power equipment, and from breakthroughs in NEV battery technology to R&D for autonomous driving systems, China has consistently set new industry standards. These technological advancements have not only enhanced the global competitiveness of China's new energy products but have also established a benchmark for global new energy technology development, contributing to the shaping of the industry's development trajectory.

China's substantial investments in new energy have generated significant technological spillover

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effects (Chen and Xian, 2020). As the adoption of Chinese new energy products increases globally, international companies and research institutions have begun to closely monitor and participate in China's new energy technological exchanges and collaborations. These exchanges and collaborations have not only facilitated the dissemination and sharing of technology and knowledge but have also sparked new ideas and opportunities for international innovation partnerships. For example, Chinese new energy enterprises have partnered with international research institutions to address technological challenges while simultaneously learning from advanced technologies and management practices. Such two-way exchange and collaboration have led to significant advancements in new energy technologies and innovations.

3. China's Transformative New Energy Industry Trajectory

3.1 Moving towards a Sophisticated Stage of Development

China's new energy industry has evolved through the nascent and rapid growth phases of the global energy transition, and now stands at a sophisticated stage of development.

Embryonic stage (1950s-1999): Faced with the challenge of energy scarcity, China began to explore new energy technologies such as small hydropower and biogas digesters. However, constrained by immature technology, low market awareness, and incomplete supply chain, the development of the new energy industry has been slow and fragmented. New energy technologies were still in the initial stages of research and development, primarily applied to small-scale, local projects.

Rapid growth stage (2010-2017): The growing global emphasis on a low-carbon economy, coupled with China's commitment to reducing carbon emissions, accelerated the development of the new energy industry. Technological advancements and supportive policies fueled rapid growth in solar and wind power capacities, expanding the markets for power batteries and NEVs. As shown in Figure 1, China's installed wind capacity surged from 29.58 GW to 163.25 GW, representing a 451.89% increase, while installed photovoltaic capacity grew from nearly zero in 2010 to 129.42 GW in 2017. China's installed power battery capacity increased from 0.8 GWh in 2013 to 36.24 GWh in 2017, and NEV sales rose from 75,000 units in 2014 to 777,000 units in 2017. During this period, China's new energy industry experienced rapid expansion despite intense competition. Companies gained competitive advantages through technological innovation and efficiency improvements. As market concentration increased, industry barriers began to emerge.

Mature development stage (2018–present): As China's new energy industry entered a mature development stage, growth rates slowed and market saturation increased, shifting the competitive focus toward efficiency and profitability improvements. Aligned with the nation's carbon peak and neutrality goals, the NEV industry experienced significant growth, driven by increased policy support, the rise of intelligent connected vehicles (ICVs), and accelerated construction of charging and energy storage infrastructure. Figure 1 illustrates that installed wind power capacity increased from 184.27 GW in 2018 to 365.64 GW in 2023, while photovoltaic power capacity grew from 174.33 GW to 392.68 GW over the same period. Installed power battery capacity surged from 56.89 GWh in 2018 to 387.7 GWh in 2023, and NEV sales climbed from 1.256 million units in 2018 to 9 million by 2023. Companies like CATL and BYD have introduced numerous innovative technologies, significantly enhancing their global competitiveness. Despite ongoing challenges related to battery range and stability, Chinese companies have increased R&D investment and market consolidation, signaling strong growth potential in this mature stage.

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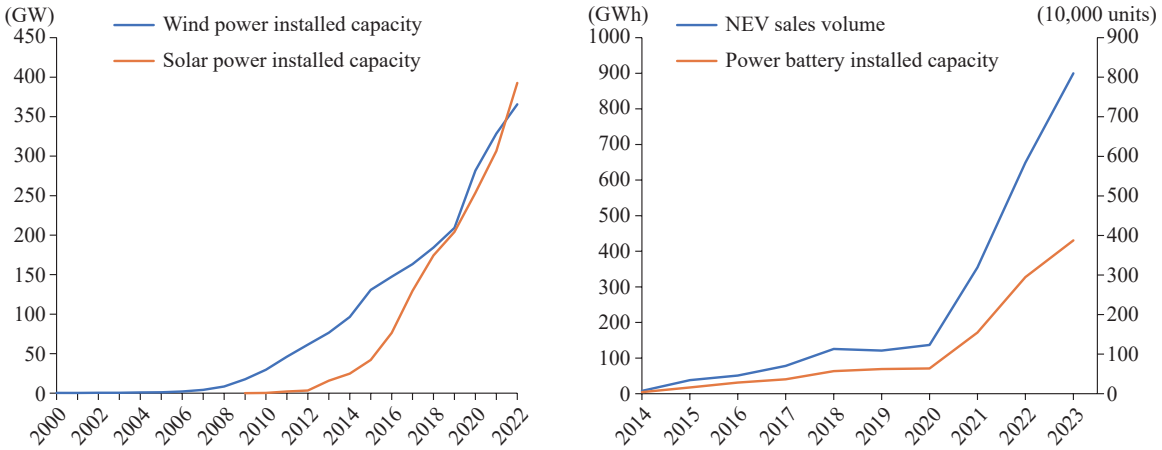

Figure 1: Change in Sales of Chinese New Energy Products

Source: Calculated based on *China Statistical Yearbook* of various years.

3.2 Continuously Strengthening Market Mechanisms

During the initial and rapid development stages, the government provided essential policy support and legal frameworks to address critical challenges, laying the foundation for the new energy industry. For instance, the government issued a series of plans (such as the *New Energy and Renewable Energy Industry Development Plan* in 2000 and the *Mid-and Long-term Renewable Energy Plan* in 2006) and decisions (such as the *Decisions on Fostering Strategic Emerging Industries* in 2010). These policy documents outlined clear industrial development directions, increased support for key industries, and established a robust service system to promote industrial growth. The Chinese government has continuously improved its legal framework to support the development of the new energy industry, enacting the *Clean Production Promotion Law* and the *Renewable Energy Law*, along with their amendments. These laws and regulations effectively promoted new energy development by providing legal safeguards for renewable energy power generation and grid connection, such as the guaranteed purchase of all renewable electricity and the establishment of a dedicated new energy development fund.

To adapt to the increasing sophistication of the industry and evolving market dynamics, the Chinese government has transitioned towards market-based mechanisms to stimulate competition in the renewable energy sector. This policy shift aims to drive industrial transformation and upgrade. Market-based electricity power reform, a green electricity trading system, and a renewable energy power quota system are key examples of these policy initiatives. Electricity market reform has laid the foundation for the new energy market. Since the implementation of the *Power Sector Institutional Reform Plan* in 2002, China's power industry has steadily progressed towards market-based operations. The 2015 *Opinions on Deepening Power Sector Reforms* outlined a path of "three liberalizations, one independence, and three strengthenings", further accelerating market-oriented reforms. In recent years, the Chinese government has intensified efforts to establish a multi-tiered and unified power market, actively developing a national power market. A series of guidelines and circulars have been issued to unify and open the power market, expanding market opportunities for new energy power. In 2017, the National Development and Reform Commission (NDRC), the Ministry of Finance, and the National Energy Administration (NEA) jointly issued the *Circular on the Pilot Issuance of Renewable-based Green Power Certificates and the Voluntary Subscription and Transaction System*. The

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official launch of the green certificate subscription system on July 1, 2017, expanded funding sources for new energy projects. Subsequent policies, such as the *Circular on Promoting the Full Coverage of Renewables-based Green Power Certificate for the Promotion of Renewables-based Electric Power Consumption* and the *Circular on Enhancing the Linkage between Green Power Certificate and Energy Conservation and Carbon Emissions Reduction Policy for the Promotion of Non-fossil Energy Consumption*, further refined the green power certificate trading system. This market-based green certificate and quota system has effectively facilitated the consumption of new energy power, leading to a steady increase in clean energy transactions. In 2021, China's market-based clean energy consumption reached 721,500 GWh (Liu, 2022).

3.3 Continuously Enhancing Endogenous Growth

In its early stages, China's new energy industry faced significant challenges, including high costs, immature technology, and weak market competitiveness. To address these challenges, the government actively supported the new energy industry through fiscal subsidies and tax breaks. Similar to the European Union's REPowerEU Plan and the *American Recovery and Reinvestment Act of 2009*, which provided substantial government support for the new energy sector, China implemented the *Renewable Energy Law in 2005*. This law effectively reduced the cost of new energy power generation and increased market competitiveness through electricity tariff subsidies, quota transactions, and other policy instruments. In addition to accelerating new energy development, these policies laid the foundation for future technological advancement and cost reduction.

Technological advancements and emergence of economies of scale have led to a significant reduction in new energy costs. For instance, in photovoltaic power generation, technological improvements have increased component efficiency while substantially reducing manufacturing costs. As industrial chains mature and market mechanisms take hold, photovoltaic power generation projects have become increasingly profitable, attracting substantial private investment. These developments have enabled photovoltaic power generation to achieve grid parity. In 2018, the NDRC, the Ministry of Finance, and the National Energy Administration (NEA) issued a policy document aimed at refining the photovoltaic electricity tariff mechanism, reducing subsidy intensity, and encouraging local governments to develop photovoltaic industrial policies and implement subsidy-free projects. Fiscal subsidies were phased out on January 1, 2021, as market-based allocation and policy improvements took effect. Since then, the feed-in tariff for centralized photovoltaic power plants has aligned with the local baseline tariff for coal-fired power generation. As of 2022, neither centralized nor distributed photovoltaic projects have received any central fiscal subsidies.

As China's power market reforms deepen and the cost of photovoltaic (PV) power generation declines rapidly, Chinese PV power has achieved grid parity—or even at lower costs. This demonstrates that China's new energy sector possesses a robust capacity for self-development, allowing it to swiftly adapt to shifting market conditions and thereby enhance market competitiveness.

4. China's New Energy Industry: Competitive Strengths

China's new energy industry is a cornerstone of the country's strategic emerging industries, providing a pathway toward a green energy transition. Over the past decade, China has emerged as a global leader in the new energy sector. China's "new three" energy products have gained global popularity due to their competitive pricing and advanced technological content.

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4.1 Abundant Mineral Resources for New Energy Development

China's rapid new energy development is underpinned by its abundant mineral resources and favorable geological mineral-forming conditions. These resources provide low-cost raw materials for the manufacturing of "new three" products, ensuring a stable supply of materials for both upstream and downstream new energy industrial chains.

First, polycrystalline silicon resources. China is the world's largest producer of polycrystalline silicon, a key material in the photovoltaic industry. Progress in photovoltaic technology and the accelerating global energy transition have led to a rapid increase in China's polycrystalline production, which reached 1.472 million tons in 2023, representing a 71.8% annual increase[2]. With low electricity costs and favorable production conditions, Xinjiang, Inner Mongolia, and Sichuan have emerged as primary polycrystalline silicon manufacturing sites, underpinning China's dominant position in global PV industrial chains.

Second, rare-earth resources. Rare earths are critical materials in the NEV industry for making high-performance electric motors, batteries, and catalysts. China has the world's largest rare-earth reserves, totaling 44 million tons and accounting for 44% of global reserves. More importantly, China has established a complete industrial chain for rare earth exploration, extraction, and application, as well as processing technology and supply capabilities for the vast majority of rare-earth resources worldwide[3].

Third, quartz and graphite resources. Quartz is a key raw material in the photovoltaic and electronics industries. China's verified high-grade quartz reserves exceed 14 billion tons, enough to supply relevant industries with stable raw materials. China has the world's largest graphite reserves, totaling 78 million tons, accounting for 27.86% of global reserves[4]. Graphite has numerous applications, including lithium-ion batteries and graphene-based new materials. Abundant reserves and high mineral quality have paved the way for rapid development in China's new energy and materials industries.

Fourth, lithium mineral resources. The abundance of lithium mineral resources as critical raw materials for NEV and energy storage technologies is critical to China's new energy industry. The lithium triangle in South America, which includes Bolivia, Chile, and Argentina, contains the world's largest lithium ore reserves. Chile has the most lithium ore reserves in the world, accounting for 35.78% of the total. China also has a relative abundance of lithium ore reserves, ranking fourth globally[5]. China's lithium ore reserves are spread across a wide geographical area, from salt lakes in the south of Qinghai Province to mineral deposits in Sichuan Province. The relative abundance of lithium-ore resources provides strong support for China's rapid NEV development.

4.2 Ultra-Large Market Advantage: Leveraging NEV Economies of Scale

China has an ultra-large market advantage as the second-largest economy in the world. This unique condition creates a large space and enormous potential for rapid "new three" development. This market advantage is reflected not only in a large consumer group with diverse needs, but also in its ability to unleash technological innovation, promote industrial upgrading, and foster internationally competitive

[2] Sina Finance: Supply-demand relationship of polycrystalline silicon as a major PV material, https: //finance.sina.com.cn/money/future/wemedia/2024-08-26/doc-inckxptr5157796.shtml.

[3] QQ.com: Comparison of rare earth reserves between China, the United States and Russia: How big is the dominant position of China's rare earth?https://news.qq.com/rain/a/20240920A031BJ00.

[4] Chinabaogao.com: China's Natural Graphite Industry: Navigating Rising Market Thresholds with Expanding Output Amid Shrinking Exports, https: //www.chinabaogao.com/market/202409/728169.html.

[5] Huaon.com: Status of Global and China's Lithium Industry Development in 2023: Majority of China's Lithium Resources Are in Salt Lakes, https: //www.huaon.com/channel/trend/947413.html.

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industrial clusters.

First, the ultra-large market provides fertile ground for the development and promotion of new technologies and products. Because of its larger population and multitiered consumer requirements, the Chinese market is very open to new technologies and has a high demand for new products. This has prompted businesses to invest in R&D and create high-end, intelligent, and environmentally friendly products to meet market demand. As a symbol of China's advanced manufacturing, the "new three" have gained consumer recognition for their technological innovation and competitive advantages.

Second, significant economies of scale have assisted businesses in lowering costs and increasing competitiveness. China's ultra-large market scale allows "new three" enterprises to profit through mass manufacturing and sales, which offsets the high upfront fixed and innovation costs (Zhou, 2024). While assisting Chinese companies in dominating the domestic market, such a cost advantage also allows them to enter the international market and become more competitive. Furthermore, economies of scale facilitated improvements to industrial chains, resulting in a benign ecosystem of coordinated upstream and downstream development.

Third, the ultra-large market allows for competition and growth across multiple technology paths. In the "new three" sector, technological innovations are critical driving forces of industrial development. China's market is large enough to support competing technology paths. Consider lithium-ion batteries: the market offers both high-energy-intensity products such as ternary lithium batteries and better value-for-money options such as lithium iron phosphate batteries. A diverse competitive landscape encourages technological innovation and industrial upgrading while also providing consumers with a variety of options.

Fourth, the ultra-large market has a significant appeal and influence on global industrial chains. China's thriving "new three" industries have prompted international corporations to focus their attention on the Chinese market and seek opportunities for collaboration. This has strengthened China's integration and cooperation with the international market, increasing its position and influence in global industrial chains.

4.3 Natural Advantage: Geographical Factors for New Energy Development

The nascent new energy industry is highly dependent on specific geographical conditions, demanding exceptional resource efficiency and environmental compatibility. In this regard, China possesses unique advantages that position it favorably for the development of new energy technologies.

First, China's vast territory spans multiple climate zones, and the diverse geographical environment provides new energy projects with a wide range of application scenarios. Photovoltaic power generation, as a key new energy component, has extremely high requirements for sunlight. Most parts of China, particularly the central and western regions, have long annual sunshine periods and strong solar radiation. Over two-thirds of China's land area has annual sunshine durations of at least 5,000 megajoules per square meter, providing ideal natural conditions for photovoltaic power plants. Sufficient sunlight resources have made photovoltaic power generation more affordable and profitable, allowing solar power to play an important role in China's new energy industry.

Second, China has abundant wind energy resources, and they are widely distributed. Its northeastern, northern, and northwest regions are ideal for building large wind farms due to their flat terrain and strong, consistent winds. Furthermore, the coastal areas also possess abundant wind energy resources. Thanks to the maritime climate and topographical features, the wind resources in coastal regions have great potential for development. Abundant wind resources provide support to wind power development

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while helping to promote the diversification and low-carbon transition of the energy structure.

Any new energy project, whether photovoltaic or wind power, can be implemented in China with proper development and widespread application. While backing up China's new energy industry development, these natural advantages open up new avenues and platforms for global new energy industry collaboration and exchange.

4.4 Human Capital Advantage: Strengthening Intellectual Support for the New Energy Industry

With the profound changes in the global economic landscape and industrial transition and upgrade, China's economic development has gradually shifted from relying on the exports of "old three" exports, i.e., apparels, home appliances, and furniture, to a high-quality development stage represented by new energy vehicles, photovoltaic products, and lithium-ion batteries, known as the "new three." In this transition, highly qualified professionals provide the driving force and intellectual support for the "new three" to thrive.

First, cultivating top-tier R&D talent. The core competitiveness of the "new three" is based on technological innovation and R&D capacity. In recent years, China has increased its investment in higher education and research institutions, as well as trained a large number of R&D personnel with an international perspective, innovative spirit, and specialized skills. These top professionals have made significant advances in new energy technology, photovoltaic material science, and battery management systems, among other critical areas. They provide the "new three" industries with unwavering innovation dynamism, assisting in product performance enhancement and production cost control.

Second, recruiting a robust workforce of skilled labor. Beyond top talent, the new energy industry requires a skilled workforce. China boasts a large pool of skilled workers with increasing levels of expertise. In intelligent manufacturing and automated production lines, China's extensive use of skilled labor has enhanced production efficiency and ensured consistent product quality. Additionally, China has invested in continuous workforce development through vocational training and re-education programs, fostering a strong human capital foundation for the growth of the "new three" industries

Third, enhancing educational systems and support. By continuously improving its educational system, China can ensure a long-term supply of talent to fuel the development of the "new three industries." From primary education to higher education, vocational training, and lifelong learning, China has established a comprehensive and well-structured educational framework. In recent years, the Chinese government has prioritized aligning vocational education with industrial demands and fostering partnerships between universities and businesses to cultivate highly skilled talent who can meet the evolving needs of the market.

Fourth, strengthening policy support and incentives. The Chinese government has implemented a series of talent policies, including talent acquisition programs, research funding, and innovation incentives, to further stimulate innovation and entrepreneurship. Additionally, efforts have been made to streamline regulatory formalities and improve the business environment, providing "new three" enterprises with efficient services and attracting top talent from both domestic and international markets.

4.5 Innovation-Driven: Increasing Technology Content of New Energy Products

The "new three" sectors have significantly contributed to enhancing product energy efficiency and reliability by rapidly adopting the latest research and development breakthroughs. A high technological content is crucial for the global competitiveness of China's "new three" energy products. China has demonstrated substantial technological leadership in the new energy industry, particularly in the following key areas:

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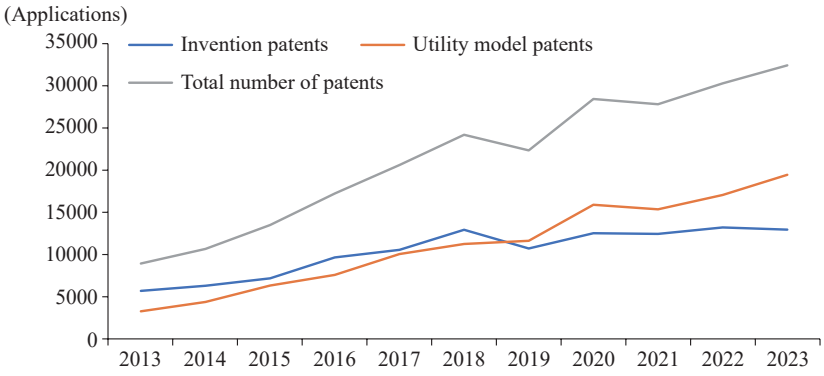

Figure 2: Growth in China's Photovoltaic Patent Filings, 2013-2023

Source: The Chinese National Patent Database, compiled by the authors.

First, battery technology. China has made significant strides in electric vehicle battery technology. Companies like CATL have achieved world-class levels in battery energy density, safety, and cycle life. Moreover, rapid advancements in emerging energy storage technologies, such as solid-state batteries, are poised to further revolutionize EV performance.

Second, vehicle technology. EV manufacturers, spearheaded by BYD and Tesla (Shanghai Gigafactory), have accelerated EV market growth through their innovative vehicle designs, efficient manufacturing processes, and advanced intelligent features.

Third, photovoltaic technology. China boasts a comprehensive photovoltaic industry chain and robust technological capabilities. As depicted in Figure 2, China's photovoltaic-related patent filings surged between 2013 and 2023. Notably, China's invention patent filings nearly quadrupled in a decade, from 8,903 to 32,443, significantly outpacing those of the European Union and the United States. Companies such as LONGi Green Energy have achieved significant breakthroughs in improving solar cell conversion efficiency, reaching world-class levels in both mono-crystalline silicon single-junction cells and crystalline silicon-perovskite tandem cells.

Fourth, photovoltaic power system integration. China has made significant strides in integrating photovoltaic systems with other energy systems, enhancing energy utilization efficiency and system stability.

4.6 Boosting New Energy Productivity: Complete Industrial and Supply Chains

In today's globally interconnected economy, the completeness of a nation's industrial and supply chain has emerged as a critical determinant of its manufacturing competitiveness. China stands alone as the only country encompassing all industrial sectors recognized by the United Nations classification. It ranks number one in the production of over 220 industrial products and has held the top position in global manufacturing capacity for 13 consecutive years. This comprehensive industrial system has enabled China to achieve substantial independence in the manufacturing of new energy products. For example, BYD produces its proprietary components, including batteries, electric motors, electronic systems, and radar, while Tesla's Shanghai Gigafactory focuses on vehicle assembly. Complete industrial and supply chains are instrumental in streamlining procurement, optimizing the distribution of raw materials and components, and consequently, reducing costs and boosting production efficiency. The combination of mass production and technological innovation has further contributed to cost reduction

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and enhanced competitiveness.

First, complete industrial chain advantage. China possesses a complete industrial chain spanning from raw materials to end products and services, encompassing research and development, design, manufacturing, marketing, and after-sales services. This comprehensive industrial advantage has streamlined operations, reduced costs, and enhanced efficiency and synergy between upstream and downstream enterprises, enabling rapid response to market demands. Notably, in the New Energy Vehicle (NEV) sector, China has developed a robust industrial ecosystem that includes core components, vehicle manufacturing, and services.

Second, strong industrial clustering effects. China has actively promoted clustered industrial development to foster efficient coordination within industrial and supply chains, resulting in the formation of a series of globally competitive industrial clusters through regional cooperation and resource integration. For instance, the Yangtze River Delta region has emerged as a significant hub for the NEV industry. Hefei City in Anhui Province, a key NEV center, hosts a diverse range of automakers. This region has established a robust supply assurance system, encompassing vehicle assembly in Anhui, chip and software R&D in Shanghai, power battery manufacturing in Jiangsu, and integrated bodywork die-casting molds in Zhejiang, creating a "four-hour industrial circle" for new energy enterprises. Inter-regional cooperation has facilitated the seamless flow of technology, talent, capital, and other production factors, accelerating the deep integration between upstream and downstream enterprises and forming an efficient and coordinated supply chain system.

Third, innovation-driven industrial upgrading. China has consistently prioritized innovation as the primary driver of industrial and supply chain improvement. By significantly increasing R&D investment and accelerating technological innovation and industrial upgrading, China has significantly enhanced the core competitiveness of its industrial chains. In the NEV sector, Chinese enterprises have achieved groundbreaking technological advancements in power batteries, electric motors, and electronic control systems, breaking foreign technological monopolies and successfully exporting to international markets. Furthermore, rapid progress in cutting-edge technologies such as intelligent connected vehicles (ICVs) and autonomous driving has infused new vitality into the NEV industry, propelling further industrial chain upgrading.

Fourth, supply chain resilience for the global market. China's industrial and supply chains have demonstrated remarkable resilience in navigating the complex and volatile international landscape. Through diversified distribution channels and globalized partnerships, Chinese enterprises have proactively expanded their global market presence and increased market share while safeguarding supply chain stability. Particularly in the NEV sector, Chinese enterprises have garnered significant international acclaim for their advanced technologies, high-quality products, and comprehensive after-sales service systems, contributing to the global sustainable development of the NEV industry.

4.7 Government Guidance for Orderly NEV Development

The Chinese government has implemented a series of targeted policies and strategic planning to cultivate a vibrant, sustainable, and well-regulated market environment, thereby promoting the healthy development of "new three" products and the high-quality growth of the NEV industry.

First, defining strategic direction and formulating long-term plans. The central government has enacted a series of strategic plans and policy documents to provide clear guidance and robust support for the development of "new three" industries, including the *NEV Industry Development Plan (2021-2035)*

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and the *Opinions of the State Council on Promoting the Sound Development of the Photovoltaic Industry*. These documents have established key performance indicators for market size, technological innovation, industrial chain improvement, and international competitiveness. Detailed industrial development plans have been developed for each market segment, outlining clear development paths, priorities, and policy initiatives to ensure steady and orderly industrial growth.

Second, offering the Chinese solution for the global energy transition. Amidst the profound global energy transition, Chinese new energy enterprises are encouraged to intensify technical exchanges and cooperation with leading international companies to drive key technological breakthroughs and upgrades. Chinese new energy enterprises are supported in delivering cost-effective new energy products to the global market, providing clean and efficient energy solutions to all nations while enhancing economic sustainability and improving people's lives.

Third, optimizing industrial layout and fostering regional coordination. The "new three" industries are encouraged to develop differentiated and specialized development patterns in various regions, taking into account local resource endowments, industrial conditions, and market needs, thereby avoiding homogeneous competition. National and provincial "new three" industrial clusters have been established to facilitate close collaboration between upstream and downstream industrial chain enterprises and enhance overall competitiveness. Efforts have been made to strengthen cross-regional policy coordination, information exchange, and resource integration to create an industrial ecosystem characterized by complementary advantages and coordinated development.

Fourth, enhancing policy guidance and stimulating market dynamism. During the initial stages of industrial development, the government increased fiscal investment in the "new three" industries, reducing corporate R&D costs and operational risks through subsidies, incentives, and discounted loan interest rates. Preferential policies, such as tax breaks and weighted tax deductions for R&D spending, were implemented to incentivize R&D investment and technological innovation. As the new energy industry matured, the government promptly initiated a subsidy phase-out mechanism to optimize industrial structure and strengthen corporate competitiveness through market-driven competition.

5. Policy Recommendations for China's New Energy Sector

The rapid emergence of the "new three" industries, including New Energy Vehicles (NEVs), lithium-ion batteries, and photovoltaics, has injected significant dynamism into China's high-quality economic development. Groundbreaking innovations in these sectors have accelerated industrial upgrading and boosted competitiveness. Moreover, they have effectively mitigated greenhouse gas emissions by providing clean and efficient energy solutions, playing a crucial role in addressing climate change and promoting a green and low-carbon transition. In the context of ongoing international energy market volatility, China's new energy industry faces several challenges, including unwarranted criticism from certain countries, technological blockades of the "large yard, low fence" type, and supply chain decoupling. To address these challenges, the Chinese government must take proactive measures to enhance policy guidance, promote technological breakthroughs, and strengthen supply chains through market mechanisms, aiming to foster high-quality development of the new energy industry.

5.1 Enhancing Policy Guidance on Industrial Layout and Resource Allocation

To address the structural capacity challenges facing the new energy industry, the Chinese government must enhance top-level policy guidance and optimize industrial layout to promote efficient

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resource allocation and foster high-quality new energy industry development.

First, clarifying industrial development planning and policy systems. The government should formulate mid- and long-term development plans for the new energy industry from a global perspective to establish clear development objectives, priorities, and safeguards. Industrial planning should be forward-looking, scientifically sound, and actionable to guide industrial development directions and provide stable policy expectations. To promote the coordinated development of new energy and energy storage projects, the government should leverage both policy guidance and market mechanisms to encourage the construction of integrated wind, solar, and energy storage projects. Successful cases such as the China National Nuclear Corporation's (CNNC) "Concentrated Solar Power (CSP) +" project in Yumen City should be emulated to promote the deep integration of new energy and energy storage technologies, enhancing overall energy system efficiency and stability.

Second, strengthening financial support and promoting green financial innovation. The government should enhance financial support for the new energy industry through tax incentives, fiscal subsidies, and financing guarantees. Financial institutions should be encouraged to adopt innovative "new energy plus green finance" financing models and utilize financial instruments such as equity, credit, and asset securitization to provide flexible and diverse financing solutions for green and low-carbon projects. Given the significant financing needs, market risks, limited fixed assets, and long investment payback periods of new energy enterprises, the government should collaborate with financial institutions to optimize credit policies, reduce corporate financing costs, and increase financing efficiency to ensure adequate financial support for new energy projects.

Third, establishing an industry information early warning and guidance mechanism. The government should establish a comprehensive industry information monitoring and release mechanism, leveraging modern IT tools such as big data and cloud computing to collect data on the new energy industry and stay abreast of industry trends and market dynamics. Enterprises should be provided timely access to accurate market information through the regular release of industry analysis reports, market forecasts, and policy interpretations via official websites, industry media, and social media. Additionally, capacity utilization in key sectors and enterprises should be monitored to assess excess capacity risks, issue timely early warning information, and guide enterprises in making rational investment decisions and pursuing sustainable development.

Fourth, implementing policy guidance and capacity regulation. The government should promptly introduce relevant policies for sectors and enterprises facing capacity risks. For example, it may adjust industrial policies and strengthen environmental regulations to prevent excessive competition. Additionally, it may encourage enterprises to enhance product value-added and competitiveness through technological innovation, transformation, and upgrading to foster sustainable development.

5.2 Fostering Breakthroughs in key technology and Upgrading New Energy Products

Driven by an innovation-led development strategy, China's new energy industry has ushered in a new era of intelligent and green development, demonstrating remarkable vitality and promising prospects. A comprehensive strategy, encompassing increased R&D investment, talent cultivation, and intellectual property rights (IPR) protection, is essential to propel significant technological advancements and comprehensive upgrades in key new energy technologies.

First, prioritizing innovation in critical technologies. Significant resources should be allocated to the development of critical technologies and address weaknesses in new energy intelligent manufacturing,

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such as efficient battery technology, smart grid technology, and advanced energy storage technology. Establishing a dedicated fund to bolster fiscal support and financial investment for R&D projects in critical sectors and core technologies is recommended to ensure adequate resource allocation for R&D activities. China's comprehensive industrial system, vast domestic market, and strong national mobilization and organization capabilities should be fully leveraged to accelerate the commercialization of R&D results and build an independent, controllable, secure, and reliable supply chain system.

Second, deepening industry-academia-research cooperation and establishing an innovation network. To facilitate the flow and exchange of innovation factors such as technology, talent, and capital, a robust industry-academia-research cooperation network should be established. Governments, enterprises, universities, and research institutions should collaborate closely to build an integrated innovation network that promotes the exchange and flow of innovation factors. More inclusive policies should be implemented to attract top-tier R&D talent from both domestic and international sources to contribute to new energy research. Additionally, a comprehensive talent development system should be established to cultivate cross-disciplinary innovation talent and provide intellectual support for the new energy industry. Incentive mechanisms, such as rewards for R&D achievements and equity incentives, should be established and refined to unleash the innovation potential and creativity of R&D personnel and foster a continuous stream of innovation.

Third, strengthening IPR protection and enhancing international competitiveness. Greater efforts should be made to protect new energy intellectual property rights (IPRs) and establish robust IPR infringement claim, protection, and overseas dispute resolution mechanisms to provide solid legal safeguards for innovation. Measures should be taken to improve IPR commercialization, transforming innovation results into productive applications and maximizing the socio-economic benefits of IPRs. China should actively participate in the development and revision of domestic and international new energy standards, internationalize Chinese standards, and enhance the competitiveness and standard-setting influence of Chinese new energy products in the global market.

5.3 Fostering Market-Driven New Energy Development

In the early stages, the new energy industry faced challenges due to market immaturity, technological limitations, and high production costs. To accelerate industrial growth, governments often resorted to subsidies. However, over-reliance on subsidies can hinder long-term competitiveness. As the new energy industry matures and technological advancements occur, phasing out subsidies becomes necessary to encourage sustainable business development driven by technological innovation and market forces. Establishing robust market mechanisms is essential for the high-quality development of the new energy industry.

First, accelerating market-based electricity tariff reforms. Power sector reforms should be deepened to establish electricity tariff formation mechanisms that can accurately reflect changing supply-demand dynamics, resource scarcity, and environmental costs. Competitive market-based electricity tariffs will stimulate effective competition in power generation and distribution, unleashing market dynamism. Renewable energy-based power generation should be encouraged to participate in market competition, and policy instruments such as green certificate trading and electricity tariff subsidies should be implemented to promote clean energy development. Additionally, incorporating environmental costs into electricity tariffs through a carbon pricing mechanism can internalize carbon emissions costs and guide the green and low-carbon transition of both power generation and consumption.

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Second, developing the green electric power transaction mechanism. New energy power companies should be empowered to directly sell green power at market-based tariffs to enhance their competitiveness. The green electric power certificate (green certificate) issuance and trading system should be refined, allowing green certificates to be used to facilitate the consumption of new energy-based electricity. The establishment of a new energy electric power quota system, requiring provincial jurisdictions to consume a specified amount of new energy electricity, can enable the turnover and compensation of environmental value through the carbon market. To increase market liquidity and risk management capabilities, the green electric power market should diversify its transaction products and methods. For instance, financial derivatives such as options and futures can be introduced.

Third, continuing to diversify transaction products and methods in the green electric power market. Introducing financial derivatives such as options and futures can enhance market liquidity and risk management capabilities. Strengthening the supervision and evaluation of new energy market entities is crucial to ensure fair, just, and transparent market practices. Cross-departmental policy coordination and communication should be reinforced to foster synergy and promote the development of the new energy industry.

5.4 Enhancing Resilience in New Energy Supply Chains

In the face of a complex and volatile international trade environment, the United States and other countries have imposed tariffs on renewable energy products and initiated countervailing investigations, aiming to contain China's burgeoning new energy industry. Under these circumstances, strengthening China's new energy industrial chains and enhancing the industry's resilience to risks becomes increasingly crucial.

First, optimizing industrial chain layout and enhancing independence and self-reliance. It is crucial to identify weak links in the new energy industrial chain, particularly in core components and critical materials. R&D investment should be increased to support corporate technological innovation and industrial upgrading, narrowing the gap with Western countries. Furthermore, upstream and downstream industrial chain enterprises should be encouraged to collaborate closely to form robust industrial ecosystems and enhance overall competitiveness. Prioritizing the development of a group of internationally competitive leading enterprises in critical mineral extraction and processing, as well as critical material and component manufacturing, is essential to increase industrial chain independence and self-reliance.

Second, expanding international cooperation for supply chain diversification. Enhancing international cooperation and exchanges is critical for reducing supply chain risks in the face of geopolitical uncertainty. It is essential to deepen capacity cooperation with Belt and Road Initiative (BRI) countries and other friendly nations, focusing on the new energy sector. By streamlining project approval processes and extending financial policy support, the government should encourage qualified new energy enterprises to participate in global market competition and expand their overseas footprint. Moreover, proactive efforts should be made to introduce advanced foreign technologies and management expertise to elevate China's international standing in the new energy industry.

Third, adjusting the import policy to encourage product imports. Considering the import dependency on specific components and raw materials, import policies should be adjusted by lowering tax rates and expanding the list of eligible source countries. Encouraging the import of more advanced and higher-quality products can help meet domestic market demand and improve product performance and

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quality. Also, it provides opportunities for domestic enterprises to engage in technical exchanges and collaborations with advanced international companies, driving industrial upgrading and high-quality development.

Fourth, enhancing recycling technology for resilient supply chains. Recycling is a crucial strategy for improving resource efficiency and reducing environmental pollution. Increased R&D investment in critical technologies such as lithium-ion battery recycling is critical, as is assisting domestic enterprises in establishing a global waste battery recycling network. Recycling overseas waste battery resources can augment domestic raw material supply and reduce reliance on primary resources. By enhancing industrial resilience and sustainability, enterprises can focus on exporting high-value-added products to expand international markets and boost competitiveness.

In conclusion, a multifaceted approach is necessary to strengthen supply chains and enhance the resilience of the new energy industry. By optimizing industrial chain layout, expanding international cooperation, adjusting import policies, and promoting recycling, a more secure, stable, and efficient new energy industrial chain can be established. This will provide robust support for the sustainable development of China's new energy industry.

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