执行摘要：中国低碳技术创新需求评估

Executive Summary: China Low Carbon Technology Innovation Needs Assessment

2021.5

碳信托是一家全球领先的独立专业咨询公司，以推动低碳经济转型为使命。我们的商业活动遍布世界各地，来自30多个国家的300余名员工分布在英国、中国、新加坡、墨西哥、南非、巴西和美国。

我们为知名品牌设计减少碳排放和提升资源效率的发展战略，为政府规划并实施节能低碳创新项目，并协助跨国公司在低碳创新及清洁技术领域进行投资。碳信托于2009年成立了中国办公室。

Carbon Trust is a leading global independent professional consulting company with a mission to accelerate the transformation of a low carbon economy. Our business activities are spread all over the world, with a global team of more than 300 experts from more than 30 countries located in the United Kingdom, China, Singapore, Mexico, South Africa, and the United States.

We design development strategies for well-known brands to reduce carbon emissions and improve resource efficiency, plan and implement energy-saving and low carbon innovation projects for the governments, and assist multinational companies to invest in low carbon innovation and clean technology. The Carbon Trust China office was established in 2009.

中关村储能产业技术联盟是中国第一个专注在储能领域的非营利性国际行业组织。储能联盟致力于通过影响政府政策的制定和储能应用的推广促进储能产业的健康有序可持续发展。

储能联盟聚集了优秀的储能技术厂商、新能源产业公司、电力系统以及相关领域的科研院所和高校，覆盖储能全产业链各参与方，共有国内、国际200+成员单位。储能联盟在协同政府主管部门研究制定中国储能产业发展战略、倡导产业发展模式、确定中远期产业发展重点方向、整合产业力量推动建立产业机制等工作中，发挥着举足轻重的先锋作用。

The China Energy Storage Alliance is the first international non-profit industry association in China focusing on energy storage. CNESA is committed to the healthy, orderly and sustainable growth of the energy storage industry through influence exerted on government policy formulation and the promotion of energy storage applications.

CNESA now serves over 200 Chinese and international members across the energy storage industry chain which includes energy storage technology manufacturers, renewable energy developers, power grid companies, research institutes and universities. CNESA, in collaboration with government authorities, has played a pivotal and pioneering role in researching and formulating China's energy storage industry development strategy, advocating industry development models, determining the key direction of mid- and long-term industry development, and integrating industry forces to promote the establishment of industry mechanisms.

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低碳技术创新是中国实现 2060 碳中和愿景的重要支撑

2015 年通过的《巴黎协定》提出了将全球平均气温较前工业化时期上升幅度控制在 2 摄氏度以内，并努力将温度上升幅度限制在 1.5 摄氏度以内的长期目标。到 2020 年底，欧盟、英国、中国、日本、韩国等主要经济体都已经承诺碳中和或净零排放。**创新技术和解决方案的研发和应用是以相对较低的成本实现全球应对气候变化目标最重要的机会。**

技术的发展一般遵循从概念到商业化的路径。在研发初期，公共资金通常具有关键作用；当技术进入具有商业化机会的应用研究和示范阶段时，私人投资将成为关键驱动因素，但仍需要直接或间接的公共资金支持政策作为激励并降低投资风险，从而帮助企业克服市场障碍。考虑到技术创新需要的大量资金投入以及有限的公共资金，需要对技术创新进行评估和优先级排序，以便公共部门投资聚焦于对实现减排目标和经济增长目标具有最大贡献的领域。

2020 年 9 月，习近平总书记在第七十五届联合国大会一般性辩论上宣布，“中国将提高国家自主贡献力度，采取更加有力的政策和措施，二氧化碳排放力争 2030 年前达到峰值，努力争取 2060 年前实现碳中和”。然而，目前已有技术很难支撑以较低成本实现中国的气候目标，亟需加快科技创新，推动能源、工业、交通、建筑等重点行业低碳技术的研发、推广和应用。**低碳技术创新对中国实现 2030 年前达峰及 2060 年前碳中和的气候目标至关重要。**

2021 年是“十四五”开局之年，也是 2060 碳中和目标提出后的第一年。结合新一轮国家中长期科技发展规划（2021-2035）以及“十四五”科技创新规划的编制，中国需要对支撑 2060 碳中和目标的重点技术创新领域和创新方向进行识别和优选，为“十四五”以及中长期技术创新方向和路线图提供指导。

在能源基金会的支持下，碳信托联合中关村储能产业技术联盟基于英国低碳技术创新需求评估经验梳理，提出了中国低碳技术创新需求评估方法学框架，并以储能技术为例对方法学进行了测试，希望为中国低碳技术创新优选提供参考与借鉴，助力中国实现 2060 年前碳中和的气候目标。

英国技术创新需求评估经验

2019 年 6 月，随着新修订的《气候变化法案》生效，英国以法律形式确立了到 2050 年实现温室气体"净零排放” 的目标，更新了 2008 年提出的 “到 2050 年温室气体排放量比 1990 年水平至少减少 80%” 的中长期减排目标。2020 年底，英国再次宣布最新减排目标，承诺到 2030 年温室气体排放量与 1990 年相比，至少降低 68%。**为实现其中长期气候目标，并保障安全可靠和经济的能源供应，英国致力于支持和推动低碳技术创新。**

为了优化公共研发资金投入并在多个公共部门之间达成共识，英国低碳创新协调小组（LCIGG）于 2010 年启动了**技术创新需求评估（TINA）项目**，对低碳技术创新需求进行评估，筛选出了最具创新价值和经济价值的技术。2018 年，为支持和优选能源系统的低碳创新，英国商业、能源和产业战略部（BEIS）启动了**能源创新需求评估（EINA）项目**。

TINA 和 EINA 项目采用了相似的方法学（见下表），首先在宏观层面筛选和识别重点技术领域，随后针对每个重点技术领域，对不同具体技术的创新需求进行详细评估。**评估过程重点估算了创新价值和经济价值两个量化指标，即创新带来的成本降低以及创新能够帮助英国实现的经济增长和就业机会。**此外，TINA 和 EINA 项目都识别了技术创新的市场障碍的，并提出了需要公共资金支持的重点创新需求。

从 TINA 到 EINA，英国对技术创新需求评估方法学进行了调整，以反映技术创新为能源系统带来的系统收益。为广泛收集数据并评估创新机会，EINA 组织了一系列行业和学术专家研讨会、针对性的专家访谈、以及相关政府部门研讨会等。

表 1 英国低碳技术创新需求评估总结（TINA & EINA）

	技术创新需求评估(TINA)	能源创新需求评估 (EINA)
技术领域	生物能源 碳捕集与封存 住宅建筑 电网和储能 供热 交通领域氢燃料 工业部门 非住宅建筑 核裂变 海上风电 太阳能光伏 海洋（波浪和潮汐）	核裂变 海上风电 潮汐能 二氧化碳捕集利用和存（CCUS） 供热与制冷 建筑构件 工业 智能系统 突破性技术 生物质与生物能源 氢能和燃料电池 交通运输
方法学 **技术领域筛选**	TINA重点技术领域的筛选主要基于两个指标： • 碳减排潜力 • 经济价值潜力	EINA 采用能源系统建模环境 (ESME) 评估各个技术领域创新的能源系统收益。重点技术领域的筛选参考模型结果。
方法学 **英国技术应用情景**	英国技术应用情景采用了能源系统建模环境（ESME）中的一组模型，其中不同技术领域的潜力采用了不同的模型情景。	EINA 项目采用了一个中心情景，假设到2050年英国温室气体排放量减少80%，与英国当时的长期减排目标相一致。
方法学 **技术评估**	技术评估流程包括： • 创新价值（定量） • 经济价值（GVA）和就业机会（定量） • 英国市场壁垒以及多大程度上可以依赖进口或海外创新（定性）	技术评估流程包括： • 创新需求评估（主要基于专家访谈和研讨会） • 商业机会评估（定量） • 市场壁垒评估（定性）
方法学 **政策建议**	基于创新需求、创新价值、英国和全球已有项目以及对政策支持的分析，TINA为公共资金支持创新提供了政策建议。	EINA更聚焦于识别需要政策支持的创新领域，并未提出具体的政策建议。
主要产出	TINA建立了强大的共享知识库，为政府研发投资和相关政策提供参考。	EINA项目识别了需要公共资金投入的重点创新领域。

基于对英国低碳和能源技术创新需求评估项目（TINA 和 EINA）的系统梳理，本文总结了英国技术创新需求评估的经验，希望为中国低碳技术创新优选提供参考与借鉴。

- 技术创新评估方法学基于科学的证据，结合定量计算与定性分析，为低碳技术重点创新方向和研发投资决策提供了有说服力的科学基础。

- 针对不同技术领域采用了一致的方法学框架，可以在技术内部和技术之间进行比较和优选。
- EINA 项目评估了技术创新的能源系统收益，这种方法有助于评估储能以及需求侧技术的系统收益。
- TINA 和 EINA 项目由负责公共资金分配的主要政府部门领导和支持，并在项目过程中充分参与，以保障研究内容能够为政策决策提供支撑。
- 不同利益相关方（包括政府部门、研究机构和产业链企业等）广泛参与到项目中，为技术应用情景选择、模型关键参数的设置提供专家意见，并共同讨论创新机会和市场壁垒，这也有助于在不同利益相关方之间形成共识。

中国低碳技术创新需求评估方法学框架

基于英国低碳技术创新需求评估（TINA）和能源技术创新评估（EINA）项目经验，以及中国技术创新评估现状，**本项目初步提出了中国低碳技术创新需求评估方法学框架，将定量分析引入创新需求评估过程，为传统的专家打分法提供量化支撑和补充。**技术优选过程分为两个阶段：

- 重点技术领域识别（宏观层面）：针对各个技术领域进行评估，确定具有较高减排潜力和经济价值的重点技术领域。
- 创新需求识别与评估（微观层面）：针对识别的重点技术领域，详细评估和识别细分技术的创新价值、经济价值与创新需求，从而优选技术创新需求。

重点技术领域识别

作为低碳技术创新需求评估的第一步，重点技术领域识别旨在通过对各个技术类别的初步分析识别中国实现低碳发展以及减排目标所需要的重点技术领域。首先基于目前工作基础和专家意见，对我国能源/电力、工业、建筑、交通等重点行业低碳技术领域进行分类和初步筛选，提出参与评估的技术领域。随后，通过文献调研和广泛的专家咨询收集相关技术参数，计算评估指标，从而识别重点技术领域。

重点技术领域的识别主要考虑碳减排潜力和经济价值潜力两个指标。其中碳减排潜力即新技术相对于传统技术的减排潜力，经济价值潜力为未来技术应用能够帮助中国实现的经济价值（简要计算方法见图 1）。技术部署情景、成本预测、碳排放强度等关键参数的选择和确定主要基于文献调研以及行业专家咨询。基于计算结果，将不同技术领域的减排潜力和经济价值划分为低、中、高三类，建立优选矩阵。优先选择碳减排潜力和经济价值潜力双高的技术领域作为低碳技术创新重点，开展下一步具体创新需求的识别与评估。

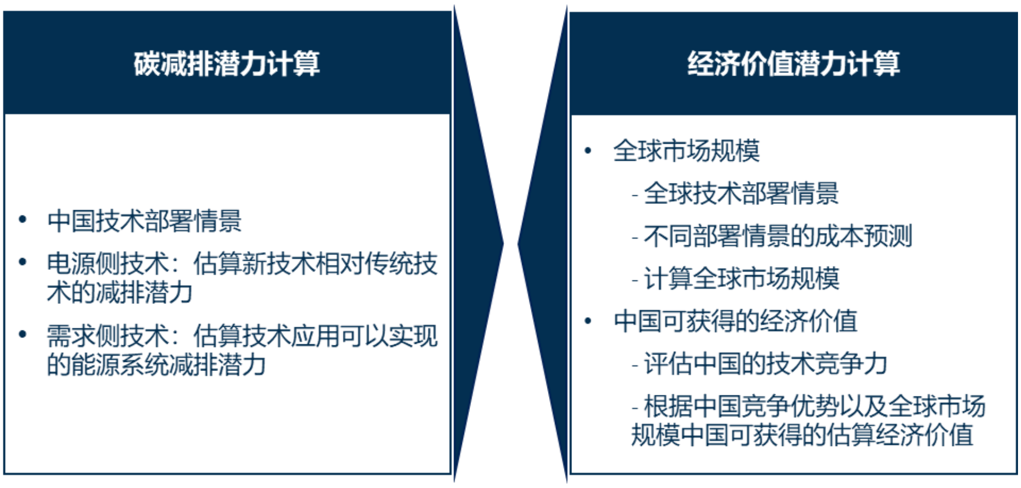

图 1 重点技术领域识别计算方法

创新需求识别和评估

针对重点技术领域，有必要对其细分技术进行深入分析，识别具体创新机会和创新需求。本项目将模型分析与专家评估相结合，提出了创新需求识别和评估的方法与流程（见图 2）：

- **应用情景预测**：分析技术在未来能源系统低碳转型中的作用，对具体细分技术在中国和全球的应用情景进行预测。技术情景的预测可以考虑不同情景，例如基准情景、与国家自主贡献目标相一致的 NDC 情景、2060 碳中和情景（高比例可再生能源）等。
- **创新价值评估**：评估创新能够实现的成本降低。创新价值是指创新带来的成本降低，即未发生技术创新时的应用成本减去技术创新后的应用成本。对于电源侧技术，可以直接评估创新为技术本身带来的成本下降；针对需求侧技术，则建议评估该技术的应用为整个能源系统带来的成本下降。
- **经济价值潜力**：评估技术能够帮助中国实现的经济价值以及社会价值。经济价值潜力的分析主要基于技术应用情景、成本下降趋势以及中国的竞争力。
- **创新机会识别**：通过专家研讨和访谈，识别针对具体技术的创新需求和机会。创新需求识别需要组织开展多轮利益相关方的讨论和访谈，邀请政府部门、科研机构以及产业链企业共同参与讨论。
- **市场障碍与国际合作机会**：基于文献调研和专家访谈，识别技术创新和发展的市场障碍以及国际合作潜力。
- **其他因素**：针对特定技术类别，可能需要对其他特定因素进行评估（例如安全性、原材料成本和可获得性等）。
- **技术优选**：基于定量分析和定性分析结果优选创新技术和机会。

图 2 重点技术领域创新需求评估流程

需要注意的是，对技术创新价值和经济价值的计算主要用于不同技术之间进行对比，而非对未来的准确预测；此外，模型假设和参数的选择很大程度上需要依赖专家意见，因此在定量和定性分析过程中，都需要广泛纳入政府、行业和企业专家，对关键假设、参数和结果进行深入论证。

储能技术创新需求评估

储能的作用及应用规模

储能将进一步推动未来能源系统向低碳化清洁化方向发展，有望支持电力系统实现零碳排放，助力实现中国“3060”碳减排目标。具体而言，储能技术是可再生能源装机规模快速增长的重要支撑，有助于提高电网接入可再生能源的能力；其次，通过提供调峰调频等辅助服务，储能技术能够提高能源互联网的灵活性和稳定性；此外，储能系统还可以为多元能源系统能量管理和路径优化提供支持，提高电网运行经济性和推动能源交易模式变革。

在国家发改委能源所、国际能源署、落基山研究所、彭博社等权威机构预测的基础上，中关村储能产业联盟（CNESA）将储能市场分为低、中、高三种不同发展情景，对中国及全球储能市场未来规模进行了预测。在“高”情景，即理想场景中，预测到 2050 年中国国内储能需求为 510GW，全球储能市场需求将达到 2440GW。该情景是对中国和全球储能市场的乐观估计，考虑了中国电力市场改革和可再生能源发展对储能的推动作用，以及电网企业、生产型用户对储能价值认同所带来的项目机会；和全球低碳发展愿景以及能源结构低碳转型对储能市场的推动作用。从装机需求上看，储能未来市场规模巨大。

储能技术创新的价值

基于专家打分和模型分析，项目估算了不同储能技术的创新价值，即创新能够带来的成本节约。**从 2018 到 2050 年，研发创新能够为中国储能领域最高实现 2500 亿的成本节约。**根据模型输出结果，不论在低、中、高哪种情景下，锂离子电池储能系统的研发创新实现的成本节约都将远超其它储能技术，其次是全钒液流电池以及压缩空气储能技术。未来锂离子电池储能技术仍可以通过技术创新等方式，进一步降低其成本，除锂离子电池外，根据技术特性，

全钒液流电池和压缩空气储能技术同样可以通过技术创新等方式大幅降低其成本，有望在未来得到大规模应用。

表 2 2018-2050 年不同储能技术通过研发创新带来的累计成本节约（百万元）

储能系统	低	中	高
锂离子电池储能系统	46,092	104,644	147,626
全钒液流电池储能系统	14,697	35,792	53,529
铅碳电池储能系统	4,060	10,453	14,365
钠硫电池储能系统	85	204	336
压缩空气储能系统	8,185	20,287	31,582
飞轮储能系统	359	1,049	1,689
超级电容器储能系统	323	807	1,230
总计	**73,802**	**173,236**	**250,356**

注：折现到 2018 年

借鉴英国 TINA 模型并采用国内储能行业一手数据，项目对全球和国内市场规模、储能技术发展的经济价值潜力以及就业机会进行了评估。**在乐观情景下，全球储能市场在 2050 年全年的规模将超过 2700 亿，中国储能市场在 2050 年全年的规模将超过千亿。**其中，中国储能市场锂离子电池市场规模将占据绝对优势地位，铅蓄电池位居第二，其次为全钒液流电池和压缩空气储能技术，其他储能技术市场规模总体较小。在物理储能技术中，压缩空气在乐观场景下具有一定的市场空间，同样飞轮储能技术作为一种新型的电力储能技术由于其功率密度高，未来在特定的场景中如电力调频领域有一定的应用，但总体市场规模较小。

表 3 2050 年中国和全球储能市场规模（2050 年 百万元 ）

技术种类	中国			全球		
	低	中	高	低	中	高
锂离子电池	27,602	36,249	67,169	111,285	144,864	207,603
钒液流电池	3,144	2,812	5,873	3,341	3,039	6,147
铅碳电池	9,320	13,312	23,185	12,192	16,667	27,630
钠硫电池	72	78	154	14,601	18,057	24,217
压缩空气储能	1,883	1,277	2,592	1,912	1,305	2,621
飞轮储能	649	690	1,405	906	1,131	1,973
超级电容器	410	374	803	424	410	865
总规模	**43,080**	**54,792**	**101,181**	**144,659**	**185,474**	**271,057**

考虑到中国在储能技术领域的竞争优势，电池储能技术的发展将为中国带来 247~477 亿元的累计经济增加值。其中，电化学储能技术中锂离子电池的商业价值最高，其次是铅碳电池和全钒液流电池储能技术，物理储能技术中压缩空气储能技术具有一定的商业价值，飞轮储能技术和超级电容器储能技术的商业价值较小。

储能技术的创新将带来更多的就业机会。在“高”情形下，储能产业 2050 年将创造超过 90 万个工作岗位，其中电化学储能产业将带来绝大多数的就业机会。

表 4 储能技术发展为中国创造的就业机会（2050 年 人）

地区	技术种类	场景		
		低	中	高
中国	电化学储能	365,423	477,663	877,597
	物理储能	266,82	21,220	43,516
创造就业机会总数		392,105	498,883	921,113

储能技术市场障碍和国际合作机会

当前市场对储能行业未来的发展持乐观态度，但仍然面临较大市场壁垒和挑战。主要集中在几个方面，一是市场机制不健全；二是国内电力市场改革较为缓慢，在一定程度上也制约了储能技术的发展；三是技术前景尚不明朗；四是储能设备还需要提高寿命及其可靠性。

目前，影响国内储能技术创新的障碍主要有：一方面企业没有形成有效和完善的技术创新机制，储能技术供应商中工程技术人员居多，不具备完备的研究开发基础条件；另外一方面在技术创新中存在技术问题，储能行业作为一个新型领域主要的表现有，技术成果不成熟，技术水平不高，技术协作攻关不力；最后，国内技术市场发育不完全，也在一定程度上制约储能行业的技术创新。正是由于以上几方面因素的存在，导致我国储能产业基础研究环节严重不足和缺位问题。

储能技术的国际合作机会主要集中在两个技术和政策层面。在技术层面，国内部分储能技术落后于国外水平，主要集中在原材料领域，包括钠硫电池的高性能碳毡、β-Al_2O_3 陶瓷管，以及有全钒液流电池用全氟磺酸树脂质子交换膜、超级电容器用纤维素纸以及高性能活性碳原材料等，存在较大的国内外合作空间。在储能政策机制和市场培育层面，储能行业发展初期阶段，中国可借鉴国外储能发展支持政策，包括给予一定的项目补贴、税收优惠等政策；同时在储能标准建设方面中国可以进一步借鉴国外经验。

其他影响因素主要包括安全性以及原材料可获得性与成本。安全已经成为锂离子电池储能产业面临的瓶颈之一，亟需开发具有本征安全的锂离子电池。从原材料可获得性与成本，当前国内锂离子电池应用规模不断上涨带来较大的供应链风险，锂原料、钴、镍、铜等稀有金属矿产资源等对外依赖程度较大。此外，由于锂离子电池规模效应，成本大幅下降，对其他技术形成较强的竞争压力，在一定程度上将挤压其他储能技术的市场份额，阻碍其他储能技术发展。

储能技术优选和创新机会

中国储能技术的重点创新和发展方向应该重点关注电化学储能技术中的锂离子电池、全钒液流电池以及物理储能技术中的压缩空气储能技术。然而从应用角度来讲，一方面还没有一种储能方案能够解决所有应用需求；另一方面部分储能技术存在资源限制，或技术突破难度较大。因此，在选择储能技术路线时应多方面考虑，除锂离子电池、全钒液流电池以及压缩空气储能外，同时以超级电容器、飞轮储能为代表的功率型储能器件以及一些具有创新价值的储能技术如钠离子电池等也同样值得关注。

表 5 不同储能技术模型及专家评价结果汇总

类别	技术	市场发展阶段	创新价值（十亿元）	经济价值（十亿元）	技术障碍	安全性/原料可获得性	创新需求	优选等级
电化学储能	锂离子电池	市场成长II期	104.6 (46.1 - 147.6)	31.6 (18.6 - 38.4)	低	中/中	高	1
	钒液流电池	市场成长I期——市场成长II期	35.8 (14.7 - 53.5)	1.1 (0.7 - 1.3)	中	高/高	高	2
	铅碳电池	市场成长II期	10.5 (4.1 - 14.4)	5.9 (3.1 - 7.3)	低	高/高	中	4
	钠硫电池	市场孕育期——市场成长I期	0.20 (0.08 - 0.34)	0.01 (0.00 - 0.01)	高	中/高	高	4
物理储能	压缩空气储能	成长I期	20.3 (8.2 - 31.6)	0.5 (0.3 - 0.6)	低	高/高	高	2
	飞轮储能	市场孕育期——市场成长I期	1.05 (0.36 - 1.69)	0.0 (0.0 - 0.1)	低	高/高	高	3
	超级电容器	市场成长I期	0.81 (0.32 - 1.23)	0.0 (0.0 - 0.0)	中	高/中	高	3
总计			173.2 (73.8 - 250.4)	39.2 (22.8 - 47.7)	——	——	——	

通过学术文献调研和专家访，**项目识别了不同储能技术的具体创新机会和创新需求**，主要总结如下表所示：

表 6 不同储能技术创新需求

技术分类	创新机会/创新需求
锂离子电池	系统由小规模向大规模发展，开发大规模高安全的锂电集成技术
	提高电池及系统可靠性（高效率，高安全、长寿命），如高安全的固态锂离子电池的开发
	加快锂电储能系统部件选型标准的确定
钠离子电池	加快低成本钠离子电池正、负极材料的产业化，如，不含贵金属或稀有金属的正极材料，以及低成本的碳材料
	关键性能指标的提升，如倍率性能、循环性能
铅碳电池	提高铅碳电池的寿命（单体寿命大于 1 万次，系统寿命 4000 次以上）及性能（荷电放电深度从目前的 40%-60%提升到 40%-80%）
	通过优化电池结构、碳材料技术的进步等，提高铅碳电池的倍率性能
	提高生产制造自动化及智能化水平
	提高铅回收技术
全钒液流电池	批量化生产电极等关键材料，提高膜的寿命，提升电堆的功率密度
	提升液流电池的装备制造水平，规模化生产以推动价格降低
	开发低成本的、新的液流电池化学体系

技术分类	创新机会/创新需求
	加强液流电池系统集成技术的研究，开发与之配套的 PCS，提升系统效率
压缩空气储能	提升整个系统的能量转换效率
	大于 100MW 级压缩空气储能系统的总体设计、部件设计、系统集成等技术的突破，推动系统模块化和标准化
钠硫电池	β-Al_2O_3 陶瓷管生产技术的突破，高性能碳毡材料的性能突破及批量化生产
	进一步突破钠硫电池的研发制造技术
	构建国内完整产业链，如石墨毡等等
飞轮储能	高速飞轮转子材料的突破，如碳纤维；加速高性能轴承及高速电机的开发，降低自放电，提高能量密度；加快变流系统的研发
	加快大容量低成本飞轮单体的开发
	提高飞轮阵列的应用设计与集成
超级电容器	隔膜及活性炭的大规模及国产化生产
	高能量密度混合电容关键技术的开发与突破

为加速储能技术创新，项目建议：第一，制定储能长期发展战略，明确储能在电力系统中的作用及价值，出台保障储能产业发展政策。第二，政府部门制定储能技术发展路线，针对当前热点及前沿技术给与重点支持，突破关键技术的研发，鼓励储能技术创新；另外通过政策引导为较为成熟的储能技术提供市场空间。第三，加强校企、院企共建实验平台的建设，推进储能关键技术国产化发展、促进创新型储能技术产业化发展。第四，加强储能专业人才培养。此外，还需完善行业标准规范，尤其是推进储能安全相关的标准；并加强储能电池回收体系建设。

低碳技术创新政策建议

增加低碳技术创新投入。增加应对气候变化和低碳技术领域研发创新的整体投入，加大国家财政科技经费投入力度，同时鼓励企业和金融机构加大研发投入。增加清洁低碳技术的研发创新投入不仅有助于应对气候变化，也对推动绿色经济增长和复苏有重要作用。

识别重点技术创新领域，优选投入方向。建议科技部牵头，联合生态环境部、发改委、工信部、财政部等涉及低碳技术创新和资金支持政策相关的部门联合成立低碳技术创新协调小组，开展实现"碳中和"的科技研发和创新需求评估，积极推进"碳中和"科技专项，基于碳减排潜力、创新价值、经济社会价值等关键指标，对重点技术创新领域以及关键技术进行优选和排序，作为科研经费分配的参照依据。

采取多元化创新激励和资金投入方式。根据技术的不同发展阶段，设计有针对性的创新支持政策和资金扶持方式。针对基础研究，以政府财政投入为主，利用国家科技重大专项、国家重点研发计划等支持重点技术创新；针对应用研究以及市场孕育期技术，一方面通过政府引导基金、奖励基金等直接提供资金支持，另一方面引导金融机构加大对技术创新的支持，降

低研发成本；针对市场推广和商业化阶段的技术，可以通过政策和标准引领，扩大绿色低碳技术的市场需求，例如健全政府绿色采购政策、制定绿色低碳技术标准等。

加强跨部门协调。加强低碳技术创新的跨部门合作，充分利用和整合不同部门的资源及技术优势，共同识别重点低碳技术创新领域和创新需求，并协调发布并实施相关政策对低碳技术研发、示范、推广和应用进行支持。例如，整合相关绿色低碳技术引导或推广目录，由各相关部委共同发布并进行推广。

激励企业研发投入和产学研协作。鼓励和支持企业开展清洁低碳技术创新，撬动企业对低碳技术创新的研发投入。

鼓励金融投资机构参与低碳技术创新投资。引导银行、私募股权和风险投资（PE/VC）等金融投资机构开展金融创新，为低碳技术创新研发、试点示范、以及商业化应用提供融资支持。

加强国际合作。一方面加强对"卡脖子"技术领域的科研攻关，另一方面也不能泛化"卡脖子"因素，导致重复研发和资金浪费。建议对 "卡脖子" 风险进行评估（如该项技术是否多个国家拥有、拥有技术国家与中国的合作中断风险等），基于风险高低确认资金投入力度。同时呼吁科技创新的国际合作和"多边主义"，加强国际应对气候变化和低碳领域的技术转移和科技成果共享，减少技术封锁，避免重复研发，将资金投入更需要技术突破的领域。

Low-carbon technology innovation is a key building block for China to fulfil its carbon neutrality 2060 commitment

The Paris Agreement, adopted in 2019, set the long-term climate goal of keeping the increase in global average temperature to well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5℃. By the end of 2020, major economies including the EU, the UK, China, Japan and South Korea have all pledged to achieve carbon neutrality or net zero emissions. **The development and large-scale deployment of innovative technologies and solutions will be the most important opportunity to achieve the global climate target in a cost-effective way.**

Technologies follow a general path from concept through to commercialisation. At the early stage of research and development (R&D), public funds usually play a key role. At the applied R&D stage with increased commercialization potential, the driving forces will become investments from private companies. Supporting policies including direct or indirect public funding are still needed to incentivise and de-risk the investments, helping companies overcome the market barriers. Considering the large amount of capital investment required for technology innovation with limited public funds, the assessment and prioritization of innovations are required, so that the public-sector investment can target those technology areas that can have the greatest contribution to achieving emission reduction targets and economic growth objectives.

President Xi, in a speech to the UN General Assembly in the September of 2020, announced *"China will scale up its Intended Nationally Determined Contributions by adopting more vigorous policies and measures, and aim to have CO2 emissions peak before 2030 and achieve carbon neutrality before 2060."* However, it is difficult for China to achieve its climate goals at a lower cost with existing technologies alone and an acceleration of low carbon technology innovation and deployment in key industries such as energy, industry, transportation and construction will be required. **Low-carbon technology innovation is critical for China to achieve peak carbon emission by 2030 and carbon neutrality by 2060.**

The year 2021 marks the launch of the "14th Five-Year Plan" and is the first year after the commitment of carbon neutrality. To support the development of China National Mid- and Long-Term Science and Technology Development Plan (2021-2035) and the "14th Five-Year Plan" Science and Technology Innovation Plan for the 14^{th} Five Year, China needs to identify and prioritize the key innovation needs to achieve its 2060 carbon neutrality goal.

Under the sponsorship of Energy Foundation, the Carbon Trust in co-operation with China Energy Storage Alliance (CNESA), has developed a methodology framework for China's low-carbon technology innovation needs assessment and has tested it for the energy storage sector, based on the UK's experiences of low-carbon technology innovation prioritisation. The overall goal is to help Chinese decision makers to adopt more effective low carbon technology innovation strategies, supporting and accelerating the achievement of China's climate targets.

UK's Technology Innovation Needs Assessments

In the June of 2019, the UK committed to a new climate target, to achieve net zero emissions by 2050, which updated the target in 2008 Climate Change Act of "reducing greenhouse gas emissions by at least 80% from 1990 levels by 2050". At the end of 2020, the United Kingdom once again announced its latest emission reduction targets, promising to reduce greenhouse gas emissions by at least 68% by 2030 compared with 1990. **In order to achieve its legally binding climate targets and ensure a safe, reliable and affordable energy supplies, the UK is committed to supporting and promoting low carbon technology innovation.**

To optimize the investment of public R&D funds and create a common understanding among multiple public sectors, the UK Low Carbon Innovation Coordination Group (LCIGG), in 2010, launched the **Technology Innovation Needs Assessments (TINAs)** project to assess low-carbon technology innovation needs, identifying the technologies with the most cost reduction and economic value. To promote and prioritize the low-carbon innovation needs across the UK's energy system, the Department for Business, Energy & Industrial Strategy (BEIS) started the **Energy Innovation Needs Assessment (EINA)** in 2018.

Both TINA and EINA processes follow a similar methodology (See **Table 1**), which, at first, select and identify key technology sectors at the macro level, then conduct detailed assessments of the innovation needs of different technologies within each technology sector. **The assessments focus on two quantitative indicators of the value of innovation and economic value,** namely, the deployment cost reduction due to the innovation and the economic value from business creation and jobs created. Moreover, both TINA and EINA processes identified the market barriers to technology innovation and the key innovation needs that require public funding support.

The 2018 EINA methodology was updated to reflect wider system benefits of innovation. To gather evidence and assess the innovation opportunities, EINA organized stakeholder engagement activities, including workshops with industry and academic, targeted expert interviews, and relevant government department seminars.

Table 1 Summary of TINA & EINA

	TINA	EINA
Technology sector	Bio-energy CCUS Domestic Buildings Electricity Networks and Storage Heat Hydrogen for Transport Industrial Sector Non-domestic Buildings Nuclear Fission Offshore Wind Solar PV Marine (Wave and Tidal)	Nuclear Fission Offshore Wind Tidal Stream CCUS Heating and Cooling Building Fabric Industry Smart Systems Disruptive Technologies Biomass and Bioenergy Hydrogen and Fuel Cells Transport
Methodology Technology Segmentation	Technology themes are prioritized against two dimensions: • Carbon abatement potential • Economic value potential	Energy System Modelling Environment (ESME) is used to evaluate the energy system benefits of innovations for various technology sectors, which inform the selection of sectors.
Methodology UK Deployment Scenario	A set of models from ESME is used to develop UK future deployment scenarios, which are further used to analyze each technology sector's potential.	The central scenario is adopted by ESME, assuming an 80% GHG emission reduction by 2050 in alignment with UK's long-term emission reduction targets at the time.
Methodology Technology Assessment	Technologies are assessed across both quantitative and qualitative dimensions including: • Value of Innovation (quantitative) • Economic value and job created (quantitative) • UK market barriers and the UK's ability to rely on others (qualitative)	The process of technology assessment includes: • Innovation needs assessment (utilising expert stakeholder workshops and interviews) • Business opportunities and job created assessment (quantitative) • Market barriers assessment (qualitative)
Methodology Recommendations for Public Sector Support	TINA provided recommendations for public sector support based upon the requirements for achieving innovation and the benefits of innovation, existing UK and global support and an analysis of potential intervention.	EINA focused on identifying barriers where policy intervention is needed rather than directly identifying policy intervention.
Output	TINA created a robust, shared knowledge base to provide reference for government R&D investment and related policy interventions.	EINA identifies the priority innovation areas that require public investment.

Based on the review of TINA and EINA methodologies, this report summarises the experience of the UK's technology innovation needs assessment processes, aiming to provide reference for China's low-carbon technology innovation prioritisation.

- The technology innovation assessment methodology, based on scientific evidence and combining quantitative and qualitative analysis, provides a robust base to guide government R&D investment decisions.
- A consistent methodology framework is used for all technology areas, which allow the comparison within and across technologies.
- The energy system benefits of innovation are assessed under EINA, which will help to capture the benefits of technologies such as energy storage and demand-side response.
- The TINA and EINA processes are led and supported by the main government departments responsible for public funding allocation. These departments are also fully involved in the project process to ensure the research can provide support for policy decisions.
- Different stakeholders including government agencies, research institutes and industry sectors are engaged to gather the evidences and discuss the innovation opportunities and market barriers, which also help to form a common understanding among different stakeholders.

A Methodology Framework for China's Low-Carbon Technology Innovation Needs Assessment

Based on the experiences from TINA and EINA processes, as well as the current status of China's technology innovation assessment, **this project initially proposes a methodology framework for China's low-carbon technology innovation need assessment, which introduces the quantitative analysis into the assessment process to supplement the traditional expert scoring method.** The technology prioritisation process is divided into two stages:

- Technology family selection and prioritization (a "macro" level analysis): to examine technological families as a whole to make an initial prioritisation and identify key technology families with highest carbon abatement and economic value potential.
- Technology innovation needs identification and prioritization (a "micro" level analysis): to analyse and prioritize the innovation needs of the technology family identified based upon the innovation value, economic value and other key indicators.

Technology family selection and prioritization

The technology family selection and prioritization is the first step of low-carbon technology innovation need assessment, aiming to identify key technology families that are most required to realise China's low-carbon development and emission reduction targets. To start the process, the technology families should be preliminarily selected based on expert opinions. To identify the key technology families, two key parameters, namely the carbon abatement and economic value, should be assessed through literature research and extensive expert consultation.

The technology family selection and prioritization assess the carbon abatement potential, which is the emission reduction potential of new technologies relative to traditional technologies and economic value potential that the deployment of such technologies can benefit China (see **Figure 1**). The carbon abatement potential and economic value potential are estimated for each technology family and defined as high- medium-low. The key parameters used to estimate carbon abatement and economic value such as deployment scenarios, carbon intensity of the technology and China's competitive advantage are determined through literature research and expert consultation. Based on the estimations, a prioritisation matrix is created and used to prioritize the technology families. The technology families with high carbon emission reduction potential and high economic value potential are then selected for further analysis in subsequent steps.

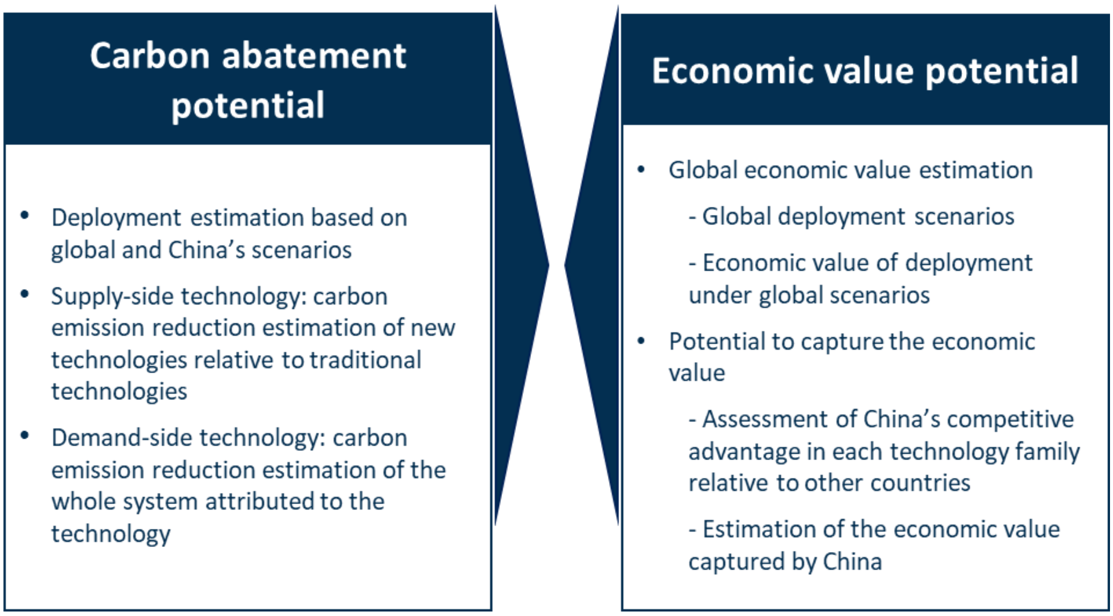

Figure 1 Technology family selection and prioritization

Technology innovation needs identification and prioritization

For identified technology families, an in-depth analysis is required to identify the innovation opportunities and needs. This project proposes the framework of technology innovation needs assessment, combining model analysis with expert evaluation (See Figure 2).

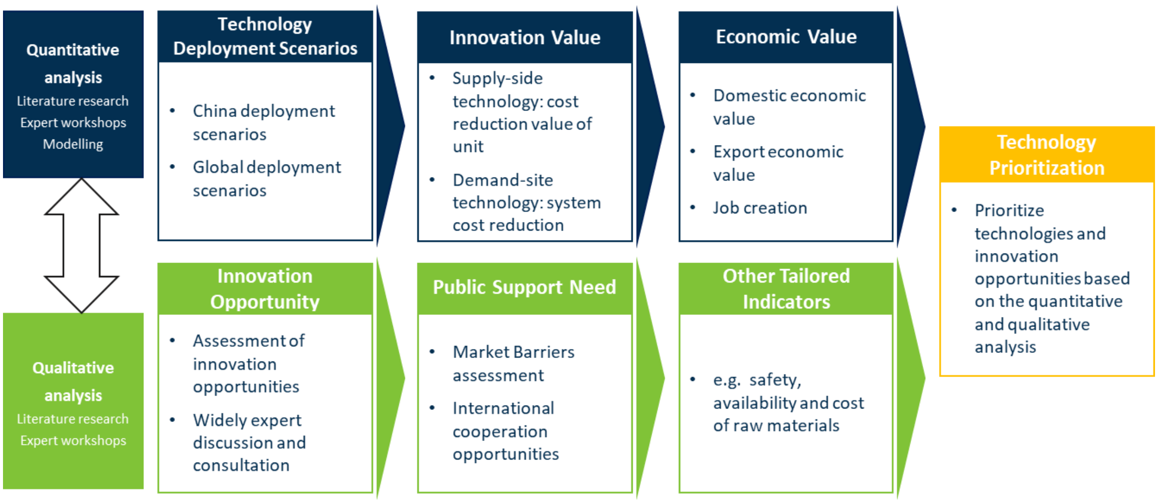

Figure 2 Process of technology innovation needs identification and prioritization

- **Technology Deployment Scenarios:** Analyse the role that a technology will play in the low-carbon transition of China's energy system, and estimate the technology deployment scenarios for China and global. Several scenarios could be considered including a BAU scenario, a scenario aligned with China's National Determined Contribution (NDC) and a 2060 carbon neutral scenario with high proportion of renewables in the energy system.
- **Innovation value**: Innovation value is the deployment cost reduction contributed by technology innovation. To assess the innovation value of a technology, separate methodologies for supply-side technology and demand-side technology are proposed. For supply-side technology, a unit cost metric is used to measure the value of innovation. For demand-side technology assessing the system benefits of deployment is more appropriate.
- **Economic value potential (business opportunity):** Business opportunities assessment including analysis of China's gross value added (GVA), and job creation. The analysis of economic value potential is mainly based on technology deployment scenarios, corresponding cost reduction trend and China's competitiveness.
- **Innovation opportunities:** The identification of detailed innovation opportunities mainly depends on expert opinions through workshops and interviews. A series of stakeholder workshops should be organized to ensure fully discussion and consultation, with the involvement of key stakeholders from government agencies, research institutes and companies across the industrial chain.
- **Market barriers and international cooperation opportunities**: The market barriers to innovation and international cooperation opportunities in each technology family should be qualitatively analysed based upon expert interviews and literature review.

- **Other Tailored Indicators:** Additional specific considerations for different technology families may be required. For example, safety is one of the key elements for energy storage technology. These indicators could be identified and assessed by experts through workshops and interviews.
- **Technology prioritization:** Prioritize technologies and innovation opportunities based on the results of quantitative and qualitative analysis.

It should be noted that the assessments of innovation value and economic value are used for indictive prioritization of different technologies, rather than an accurate prediction for future scenarios. The assumptions and parameters used in the model are highly reliant upon expert opinions, and it is therefore necessary to extensively involve key stakeholders to conduct in-depth discussions of assumptions, parameters, and results during both qualitative and quantitative analysis.

Innovation Needs Assessment for Energy Storage Technology

Energy Storage: Role and Scale of Applications

Energy storage will help to support the development of the clean, low-carbon energy system of the future. Energy storage technologies will support the power system's achievement of zero carbon emissions and help China achieve its "30&60" carbon emissions reduction target. Energy storage is an important supporting technology for the rapid increase in installed renewable energy, and helps improve the grid's ability to connect to renewable energy. By providing ancillary services such as peak shaving and frequency regulation, energy storage technology can also improve the resilience and stability of the "Internet of Energy." In addition, energy storage systems can also provide support for energy management and path optimization of the multi-energy system, improve the economic benefits of grid operation and promote the transformation of energy trading models.

Based on the forecasts of authoritative organizations such as the National Development and Reform Commission Energy Institute, International Energy Agency, Rocky Mountain Research Institute, Bloomberg, etc., the China Energy Storage Alliance (CNESA) has divided the energy storage market into three different development scenarios: low, medium, and high, and forecasted the future scale of the global energy storage market. In the "high development" scenario, or the ideal scenario, China's domestic energy storage demand is predicted to reach 510GW by 2050, while global energy storage market demand will reach 2440GW. This scenario is an optimistic estimate of the energy storage market in China and globally, taking into account the role of China's power market reform, co-development of renewable energy with storage, and project opportunities brought by the recognition of energy storage's value by grid companies and industrial manufacturing users. The scenario also considers how the vision for global low-carbon development and the low-carbon transformation of the energy structure will promote the energy storage market. From the perspective of installed capacity, the future market for energy storage is huge.

The value of energy storage technology innovations

Based on expert scoring and model analysis, the project estimates the innovative value of different energy storage technologies, that is, the cost savings that innovation can bring. **From 2018 to 2050, R&D innovations can achieve up to 250 billion RMB in cost savings in China's energy storage sector.** According to the results of the model, regardless of whether the low, medium, or high development scenario is realized, the cost savings achieved by R&D and innovations in lithium-ion battery energy storage systems will far exceed other energy storage technologies, followed by vanadium flow batteries and compressed air energy storage technologies. Future lithium-ion battery energy storage technology costs can still further be reduced through technological innovation. In addition to lithium-ion batteries, based on technical characteristics, vanadium flow batteries and compressed air energy storage technologies costs can also be greatly reduced through technological innovations. These technologies are also expected to be applied on a large scale in the future.

Table 2 Cumulative cost savings of different energy storage technologies through R&D and innovation from 2018 to 2050 (RMB million)

Energy Storage System	Low	Medium	High
Lithium-ion battery (Li-ion)	46,092	104,644	147,626
Vanadium Redox Flow Battery (VRB)	14,697	35,792	53,529
Lead-carbon battery	4,060	10,453	14,365
Sodium-sulfur battery (NaS)	85	204	336
Compressed air	8,185	20,287	31,582
Flywheel	359	1,049	1,689
Supercapacitor	323	807	1,230
Total	**73,802**	**173,236**	**250,356**

Note: Discounted to 2018

Drawing on the UK TINA model and using first-hand data from the domestic energy storage industry, this project assesses the scale of the global and domestic markets, the economic value potential of energy storage technology development, and employment opportunities. **Under the optimistic scenario, the global energy storage market will exceed 270 billion RMB in 2050, and the Chinese energy storage market will exceed 100 billion RMB in 2050.** Among these markets, the lithium-ion battery market will occupy a dominant position in China's energy storage market, with lead batteries in second place, followed by vanadium flow batteries and compressed air energy storage technology. Other energy storage technology markets will generally remain small. Among physical energy storage technologies, compressed air will have a portion of market space in optimistic scenarios. Similarly, flywheel energy storage technology, as a new type of electric energy storage technology, will see applications in specialized scenarios such as power frequency regulation due to its high-power density, though its overall market scale will remain relatively small.

Table 3 The scale of the Chinese and global energy storage market in 2050 (RMB Million)

Technology	China			Global		
	Low	Medium	High	Low	Medium	High
Li-ion	27,602	36,249	67,169	111,285	144,864	207,603
VRB	3,144	2,812	5,873	3,341	3,039	6,147
Lead-carbon	9,320	13,312	23,185	12,192	16,667	27,630
NaS	72	78	154	14,601	18,057	24,217
Compressed air	1,883	1,277	2,592	1,912	1,305	2,621
Flywheel	649	690	1,405	906	1,131	1,973
Supercapacitor	410	374	803	424	410	865
Total	43,080	54,792	101,181	144,659	185,474	271,057

Considering China's medium-high competitive advantages in many energy storage technologies, the development of such technologies will bring China a cumulative economic growth value of up to 24.7-47.7 billion RMB. The commercial value of lithium-ion batteries is the highest among electrochemical energy storage technologies, followed by lead-carbon batteries and vanadium redox flow batteries. Among physical energy storage technologies, compressed air energy storage technology has some commercial value. The commercial value of flywheel and supercapacitor energy storage technologies is relatively small.

Energy storage technology innovations will bring more employment opportunities. In the "high development" scenario, the energy storage industry will create more than 900,000 jobs by 2050, of which the electrochemical energy storage industry will bring most of the employment opportunities.

Table 4 Employment opportunities created by energy storage technology development in China (by 2050; units: persons)

Region	Technology	Scenario		
		Low	Medium	High
China	Electrochemical energy storage	365,423	477,663	877,597
	Physical energy storage	26,682	21,220	43,516
Total number of jobs created		392,105	498,883	921,113

Energy storage technology market barriers and opportunities for international cooperation

The current market holds an optimistic attitude to the future development of energy storage industry, though it still faces major market barriers and challenges. These are concentrated in several aspects. First, the market mechanism is imperfect. Second, domestic power market reforms have been relatively slow, which, to an extent, also restricts the development of energy storage technologies. Third, technological development prospects are still unclear; fourth, improvements in lifespan and reliability of energy storage equipment is still needed.

At present, a number of barriers affecting domestic energy storage technology innovations exist. On the one hand, companies have not formed a technology innovation mechanism that is effective and comprehensive, and energy storage technology vendors are comprised mostly of engineers and technicians who do not possess the basic capabilities for research and development. On the other hand, technical problems exist in technology innovation. These problems arise from the energy storage industry's nascent stage with immature technical achievements, low technical levels, and weak technical collaboration. In addition, domestic technology markets have achieved only a limited degree of maturity, which has to a certain extent also restricted technology innovations in the energy storage industry. Due to these combined factors, foundational energy storage industry research is seriously insufficient and absent.

International cooperation on energy storage technology is mainly at the technical and policy level. At the technology level, some domestic Chinese technologies lag behind those of their foreign counterparts, primarily in raw materials, such as high-efficiency carbon felt and β-Al2O3 ceramic tubing used in NaS batteries, perfluorinated sulfonic acid resin membranes used in vanadium flow batteries, and cellulose paper and high-efficiency activated carbon used in supercapacitors. Materials such as these provide great potential for international and domestic collaboration. At the energy storage policy mechanism and market development level, the energy storage market in China is still at an early stage. There are many opportunities for China to learn from foreign energy storage development support policies, such as project subsidy and tax incentive policies. China can also learn from foreign experience in the creation of energy storage standards.

Other factors mainly include safety as well as the availability and cost of raw materials. Safety issues have already become one of the key bottlenecks that the Li-ion battery energy storage industry faces and the industry is in urgent need of Li-ion batteries that are intrinsically safe. The availability and cost of raw materials is also a challenge with the increasing scale of Li-ion battery applications creating pressure on the supply chain and increasing external dependence on lithium raw materials, cobalt, nickel, copper and other rare metal mineral resources. In addition, due to the increasing scale of Li-ion battery production, costs have dropped significantly, and strong competitive pressure has been placed on other technologies. This pressure will squeeze the market share and hinder the development of other energy storage technologies.

Energy storage technology prioritisation and innovation opportunities

The key focus of technical innovation and development in China should be Li-ion batteries, VRB and compressed air physical energy storage technologies. However, one key challenge is that there is no universal solution that can meet the requirements of all applications. Another challenge is that some energy storage technologies are either resource-limited or face difficulties in achieving technical progress. Therefore, many aspects should be considered when planning energy storage technology development routes. In addition to Li-ion batteries, VRB and compressed air, other technologies worthy of attention are power-type energy storage devices such as supercapacitors and flywheel energy storage, as well as innovative energy storage technologies such as sodium-ion batteries.

Table 5: Summary of innovation potentials and technology prioritization of different energy storage technologies

Category	Tech	Market Development Stage	Innovation Value (RMB Billion)	Economic Value (RMB Billion)	Technology Barriers	Safety/Material Availability	Need for Innovation	Priority Level
Electrochemical energy storage	Li-ion	Market Growth phase II	104.6 (46.1 - 147.6)	31.6 (18.6 - 38.4)	Low	Medium/Medium	High	1
	VRB	Market Growth phase I——Market Growth phase II	35.8 (14.7 - 53.5)	1.1 (0.7 - 1.3)	Medium	High/High	High	2
	Lead-carbon	Market Growth phase II	10.5 (4.1 - 14.4)	5.9 (3.1 - 7.3)	Low	High / High	Medium	4
	NaS	Market Incubation Phase—— Market Growth phase I	0.20 (0.08 - 0.34)	0.01 (0.00 - 0.01)	High	Medium / High	High	4
Physical energy Storage	Compressed air	Growth phaseI	20.3 (8.2 - 31.6)	0.5 (0.3 - 0.6)	Low	High / High	High	2
	Flywheel	Market Incubation Phase —— Market Growth phaseI	1.05 (0.36 - 1.69)	0.0 (0.0 - 0.1)	Low	High / High	High	3
	Supercapacitor	Market Growth phaseI	0.81 (0.32 - 1.23)	0.0 (0.0 - 0.0)	Medium	High / Medium	High	3
Total			173.2 (73.8 - 250.4)	39.2 (22.8 - 47.7)	——	——	——	

Through academic literature research and expert interviews, the project identified the specific innovation opportunities and needs of different energy storage technologies, which are summarized as follows:

Table 6 Innovation needs of different energy storage technologies

Technology	Innovation Opportunities/Needs
Li-ion	System scales are increasing, and there is increasing demand for safe, large-scale Li-ion battery integration technology
	Improvements in the reliability of batteries and systems (high efficiency, increased safety, long lifespans), such as the development of a safe solid-state lithium-ion batteries
	Increase the speed in which the selection criteria for Li-ion battery energy storage system components is determined
Sodium-ion	Acceleration of the industrialization of low-cost sodium-ion battery cathode and anode materials, such as cathode materials that do not contain precious metals or rare metals, and low-cost carbon materials
	Improvements in key performance indicators, such as rate performance and cycle performance
Lead-carbon	Improvements in the lifespan and performance of lead-carbon batteries (including improved unit lifespan of more than 10,000 cycles and system lifespan of more than 4,000 cycles, and performance improvements including enhanced discharge capabilities from the current 40%-60% to 40%-80%)
	Improvements in the performance of lead-carbon batteries by optimizing battery structure and advancing carbon material technology.
	Improvements in production automation and “smart” technologies
	Improvement in lead recycling technology
VRB	Mass production of key materials such as electrodes to prolong the life of the membrane and increase the power density of the stack
	Improvements in the equipment manufacturing level of liquid flow batteries, price reduction through production at scale
	Development of new, low-cost flow battery system chemistries
	Strengthen research in flow battery system integration technology, develop supporting power conversion systems (PCS), and improve system efficiency
Compressed air	Improvements in the energy conversion efficiency of the entire system
	Improvements in the overall design, component design, system integration and other technological advancements of compressed air energy storage systems greater than 100MW, as well as promotion of system modularization and standardization
NaS	Advancements in β-Al2O3 ceramic tube production technology, performance advancements and development of mass production of high-performance carbon felt material
	Further advancements in NaS R&D and manufacturing technology
	Building of a complete domestic industrial supply chain, such as for graphite felt and other materials
Flywheel	Advancements in high speed flywheel rotor materials, such as carbon fiber; accelerated development of high-performance bearings and high-speed motors, reduced self-discharge, improved energy density; accelerated research and development of converter systems
	Increase the development speed of large capacity and low-cost flywheel units
	Improvements in the application design and integration of flywheel arrays
Supercapacitor	Large-scale and domestic production of diaphragms and activated carbon
	Development of key technologies for high energy density hybrid capacitors

To accelerate energy storage technology innovation, the project proposes the following: First, formulate a long-term development strategy for energy storage, clarify the role and value of energy storage in the power system, and introduce policies that will ensure continued development of the industry. Second, government departments should identify the development route for energy storage technology, provide support to new and cutting-edge technology R&D and encourage energy storage technology innovation, and provide market space for more mature energy storage technology through policy guidance. Third, strengthen the construction of collaborative experimental platforms built by universities and private companies, promote the localization of key energy storage technology development, and facilitate the industrialized development of innovative energy storage technologies. Fourth, strengthen the training of energy storage professionals. In addition, it is also recommended to improve industry standards and regulations, especially safety related standards, and strengthen the construction of energy storage battery recycling systems.

Policy Recommendations on Low-Carbon Technology Innovation

Increase investment in low-carbon technology innovation

Increase overall investment in R&D and innovation on climate related and low carbon technologies, through increasing public investment directly and encouraging private investment from private companies and financial institutions. The investment in clean and low carbon technology innovation will not only accelerate achieving climate targets, but also promote the growth and recovery of the green economy.

Identify key innovation sectors and prioritize innovation needs

It is recommended that the Ministry of Science and Technology, the Ministry of Ecology and Environment, the National Energy Administration and other departments to jointly establish a low-carbon technology innovation coordination group, to conduct innovation needs assessment for achieving "carbon neutrality", and to actively develop the Science and Technology Development Plan for Carbon Neutrality. Identify and prioritize technology innovation fields and opportunities inform public sector investment, based on key indicators including carbon emission reduction potential, value of innovation, and economic value.

Promote diversified innovation incentives and financial support mechanisms

Taking the varied development stages of different technologies into account, design targeted innovation support policies and financial support mechanisms. It is recommended that for basic research, public investment should be the mainstay, and national science and technology development projects and national key research and development plans should be implemented to support key technological innovations. For applied research and market-incubating technologies, the government should provide direct financial support through public funds such as government guide funds and incentive funds, as well as encourage financial institutions to increase support for technology innovation and reduce R&D cost. For technologies at the market promotion and commercialization stage, policies and standards should be developed to enable the deployment of green and low-carbon technologies. Example measures include government green procurement policies and green and low-carbon technology standards.

Facilitate cross-departmental coordination

Strengthen cross-departmental cooperation on low-carbon technology innovation. Integrating the resources and advantages of different departments, jointly identify the low-carbon technology innovation needs, and release policies to support the R&D, demonstration, and deployment of low-carbon technologies. For example, relevant ministries and commissions could consider to integrate relevant green and low-carbon technology catalogs and work together to promote these technologies.

Encourage private industry R&D investment and the collaboration between industry, university and research institutes

Encourage and support the private industry on clean and low-carbon technology innovation, and mobilize R&D investment on low-carbon technology from the private sector.

Encourage financial institutes to support low-carbon technology innovation

Guide financial investment institutions such as banks, private equity and venture capital (PE/VC) to carry out financial innovation, and provide financing support for R&D, demonstration, and deployment of innovative technologies.

Strengthen international cooperation

Strengthen R&D on "bottlenecked" technologies, while at the same time stop the generalization of "bottleneck" factors to avoid repeated R&D and waste of funds. It is recommended to evaluate the risk of “bottlenecks”, assessing if the technology is owned by multiple countries and if there is risk of interruption of cooperation between the technology owner and China. At the same time, international cooperation on low carbon technology innovation should be encouraged, to strengthen the technology transfer and sharing in the field of climate change and low carbon development, reduce technology blockades, avoid repetitive investment on technology innovation.