电动车动力电池的循环经济体系的构建

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１．电动车时代电池市场的拓展

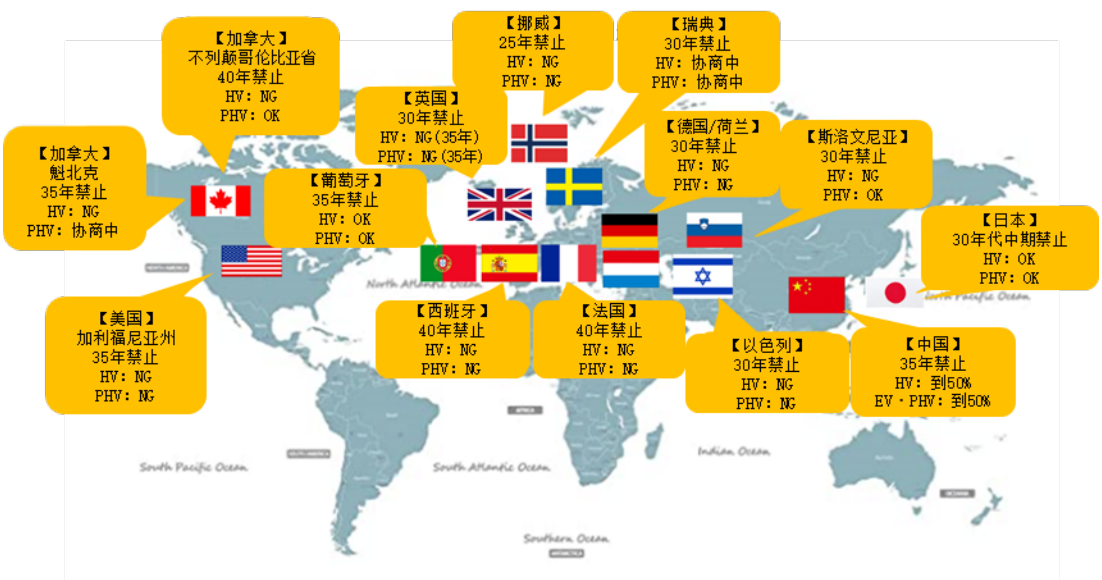
（１）全球电动车发展趋势

2009 年，三菱汽车推出了全球首款量产电动车“i-MiEV”，2010 年，另一家日本企业日产汽车也推出了“LEAF”，标志着普通市场开始向电动车方向转变。虽然由于电动车的高环保性，电动车的普及在人们的意料之中，但由于电动车的利润率比汽油车低，各大厂商在全球范围内并不活跃，电动车直到 2010 年代中期才开始普及。

中国市场是全球最早大规模推广电动车的市场。自 2010 年起，凭借所谓的〞十城千辆〞政策，中国各个城市开始贯彻落实，2013 年起，大规模的补贴政策出台，促进了该体系在包括普通家庭在内的众多人群中的普及。除补贴外，政府还通过在车牌管理对电动车等车辆实施优惠政策，以及支持充电基础设施建设的政策，改善电动车的普及环境。 在这些政策的共同作用下，2018 年中国占据了全球电动车销量的绝大部分，并持续至今。

为了应对电动车在中国市场的扩张，中国的整车制造商固然积极生产新能源汽车，但从 2019 年前后开始，特别注重中国市场的欧美品牌也逐渐开始转向电动车。例如，德国大众汽车公司宣称要在 2028 年之前生产 2200 万辆电动汽车，到 2030 年，新车销量的 40%将是电动车。美国通用汽车将在 2025 年之前将旗下 30 款车型全部生产成电动车，到 2035 年，其所有新车都将是电动汽车或 PHV。吉利汽车旗下的瑞典沃尔沃最为激进，表示到 2025 年将有 50%的新车生产为电动车，2030 年将 100%生产电动车。这样一来，我们就达到了各个厂家所制定的具体的数字目标。

图 1 各国导入电动车的目标



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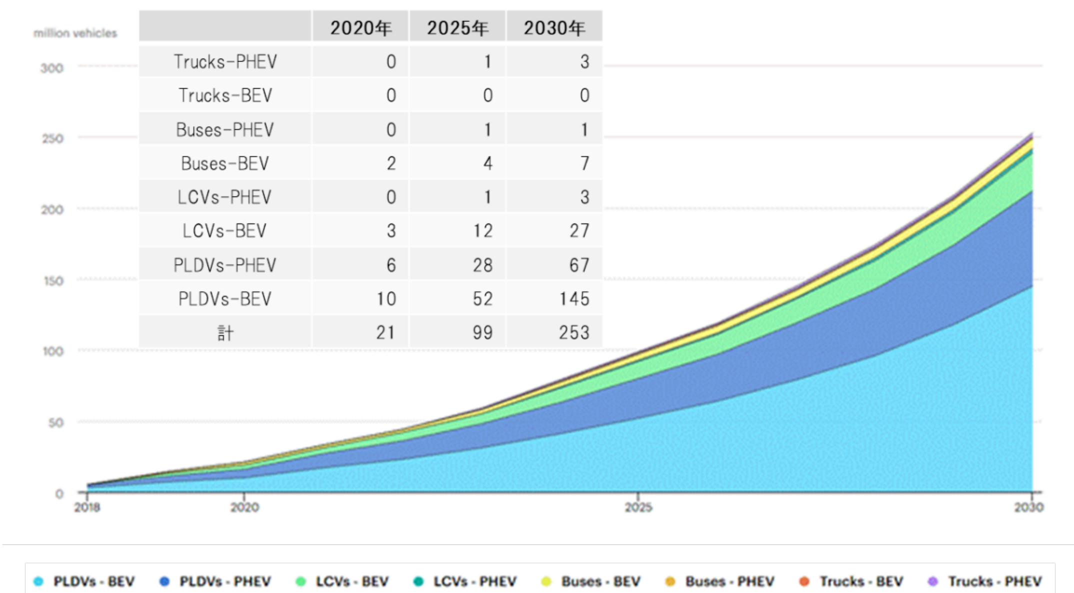
此外，欧洲各国政府也开始陆续制定2020年各自国内市场的电动化比例目标。德国和英国制定了到2030年禁止销售汽油等车辆（包括柴油车，下同）的政策。德国和英国也将分别在2030年和2035年时禁止销售PHV。法国计划在2040年禁止销售汽油车等。最前卫的目标是由挪威设定的，它将在2025年前禁止销售汽油车以及PHV。早在2015年，欧洲国家就制定了这样的数字目标，但当时并没有实际销售电动车，所以这些目标的可行性从一开始就受到了质疑。这一次，目标似乎变得更加现实，部分原因是厂家方面在不断地取得进展。

关于中国未来的目标，从中国汽车工程学会在2020年10月提出的《新能源汽车技术路线图》中可以看出截止到2035年的前景预估。根据路线图，到2035年，50%的车辆将是HV，剩下的50%将是EV或PHV，这样汽油车有望消失。目前，中国电动车与PHV的比例约为4:1，预计将保持在这一水平，甚至会有所提高。

根据中国和欧洲政府的上述政策以及各大厂商的动向，IEA(国际能源署)提出了对新能源汽车扩大普及的预测。 根据IEA的数据，预计2020年电动车将大幅增长，2020年电动车上路数量约为1200万辆，但预计到2030年将增至1.79亿辆。

中国是推动电动汽车扩张的市场，其次是欧洲。这一构成在整个 2020 年代都将保持不变，中国市场的趋势将是塑造电动车相关市场的重要因素。

图 2 全球电动车导入辆数预测



	2020年	2025年	2030年
Trucks-PHEV	0	1	3
Trucks-BEV	0	0	0
Buses-PHEV	0	1	1
Buses-BEV	2	4	7
LCVs-PHEV	0	1	3
LCVs-BEV	3	12	27
PLDVs-PHEV	6	28	67
PLDVs-BEV	10	52	145
計	21	99	253

（资料）IEA”Global EV Outlook 2020”

如果按照 IEA 的预测，2030 年有 1.79 亿辆电动车上路，并假设 5 年的更新换代期，全球每年将售出 3600 万辆电动车。

另一方面，估计中国新车销量将从目前的 2600 万辆左右增长到 2030 年的 3000 万辆左右（虽然还有进一步增长的可能，但这里假设的是 3000 万辆

这个高度可行的数字)。如上所述，汽车销量的50%将是新能源汽车，其中80%是电动汽车，所以2030年电动汽车的销量将达到1200万辆。预计中国市场将占全球电动车销量的三分之一左右，虽然会低于目前 50%以上的数字，但可以说中国市场将是整个2020年代电动车的推动力。

（２）大量产生的废旧电池

随着电动车的大规模普及，车载电池的规模也将扩大。各大电池厂商在过去几年中多次投入大规模的生产扩张。例如，全球最大的电池制造商CATL宣布，未来将把产能从目前的36GWh扩大到115GWh，随着2020年代电动车市场的扩大，产能还有进一步扩大的可能。

部分电动车在多次被作为二手车反复利用之后，从售出后经过一定时间就会被处理掉。因此，当电动车废弃后拆解时，车载电池会从车体中取出，成为废旧电池。如同目前在中国和世界其他地区，电车分离和BaaS(Business as a Service)运转一样，预计车载电池的使用周期将不同于电动车本身的产品寿命。

在这里，我们想总结一下与电动车分离再利用的车载电池的容量规模，虽然BaaS有发展，但我们先用一个简单的模型估算一下2030年的规模。再利用电池的容量规模是由使用过的电池数量乘以每只使用过的电池的容量来

计算的。

首先，我们要考虑废旧电池的数量。如果我们假设一个简单的模型（处置期为5年，与置换期相同，2020年至2030年市场线性扩张），估计2025年全球处置的电动车数量为252万辆，中国为136万辆，2030年全球为1925万辆，中国为668万辆。

其次，我们整理一下废旧电池的容量。预计未来电动车安装的电池容量将呈现两极分化趋势。换句话说，高端品牌等需要较长巡航里程所安装的电池会变大，而专门用于本地驾驶的车辆所安装的电池会变小。目前，每辆电动车都安装了容量约为40kWh的电池，但更大的电池预计将增长到约80kWh，而容量为10kWh以下的小型电池有望出现。因此，我们假设平均值为40千瓦时。此外，我们假设废旧电池的存储容量将比新电池低20%左右，每个电池的容量约为32千瓦时。

根据以上情况，预计2025年全球汽车电池再利用的容量规模为80.6GWh，中国为43.5GWh；2030年全球为616.3GWh，中国为213.8GWh。如果我们假设市场规模为每千瓦时5万日元，那么仅在中国就有10万亿日元左右。

预计再利用的电池将被用作ESS，并假定使用后的寿命约为5年。基于这一假设，2030年全球再利用电池的累计容量约为1742.4GWh，中国为643.2GWh。如果按照电动汽车同时放电的供电能力计算，这意味着仅中国就

将拥有约 60 座核电站的供电能力。

另外，车载电池中有磷酸铁锂电池和三元锂电池，估计未来三元类电池的比例会增加，根据要安装的电动车的属性，它们会分开，共存。由于三元电池中含有大量的稀有金属，因此有回收的趋势，但如果在生命周期内寻求经济价值，则无论如何都会被认为在 ESS 等情况下重新使用三元电池是合理的。

图 3　电动车电池再利用的规模推演

电动车销售辆数(万辆)

	2020年	2025年	2030年
全球	252	1926	3600
中国	136	668	1200

电动车报废辆数(万辆)

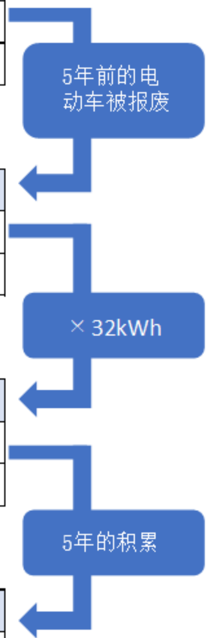
	2020年	2025年	2030年
全球	60	252	1926
中国	33	136	668

再利用电池的容量规模(GWh)

	2020年	2025年	2030年
全球	19.2	80.64	616.32
中国	10.6	43.52	213.76

再利用电池的累计规模(GWh)

	2020年	2025年	2030年
全球	—	249.6	1742.4
中国	—	135.2	643.2



（资料）（资料）基于各种公开资料日本总研整理

2． 电动汽车电池再利用的现状

（1）电动车电池再利用的趋势

根据中国行业协会的统计，2018 年和 2019 年，中国废旧电池分别为6.2GWh 和 15.33GWh. 在 2016 年之前，很多新能源车都使用磷酸铁电池，因为新能源汽车主要是公交车和物流车。初期大部分再利用的是磷酸铁锂电池，

但未来三元电池的量会增多。

自 2009 年起，中国政府在推广新能源汽车政策的同时，一直倡导建设动力电池回收利用体系；2016 年，政府公布政策，扩大生产责任，全面实施电动汽车电池再利用体系建设，明确汽车制造商的回收责任实体。 此外，2018 年 5 月，工信部等 7 家政府部门发布了《关于开展新能源汽车动力蓄电池回收利用示范工程的通知》，引发了由地方政府主导的全国回收利用示范工程的启动。

自 2018 年 5 月起，京津冀、广东、深圳、浙江、甘肃、江苏、河南、湖北、青海、福建、江西、安徽、山西等 18 个地区入选示范工程目标地区。

这些地区编制了地方版《新能源汽车动力蓄电池回收利用示范项目实施方案》，在废旧电池回收网络、梯次利用、拆解和回收等领域开展技术示范、商业模式示范、培育代表性企业。

根据本地区或本地区代表性企业的特点，每个地区的示范项目都有自己的特色。

例如，在京津冀地区的示范项目中，21 家再利用企业提出的 18 个示范项目获得批准。其中，回收网络建设 3 项，梯次利用 9 项，拆解 3 项，回收 1 项。186 可见，梯次利用项目最多。回收网络搭建、梯次利用、拆解、回收项目等，示范项目的平衡性较好。

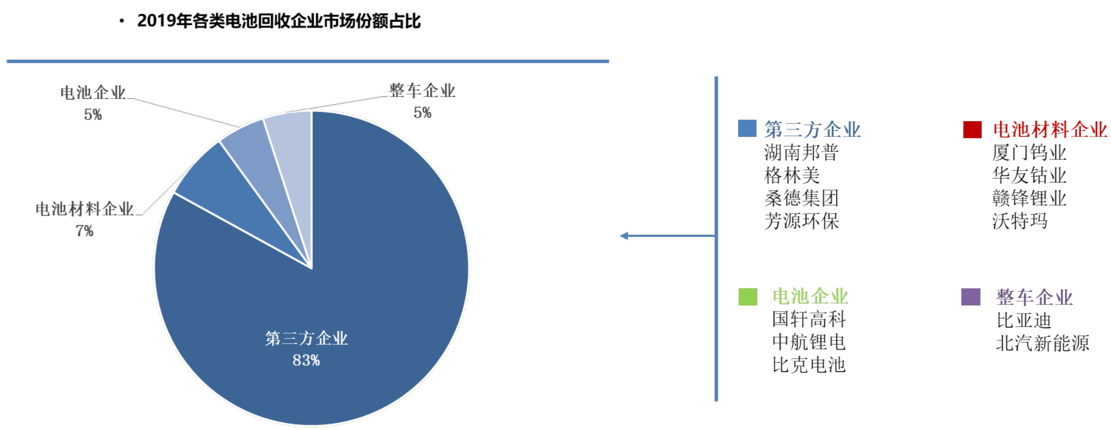
在湖南省，由于材料回收企业是经营主体，所以选择了很多回收项目。在获批的 45 个示范项目中，回收网络建设 16 个，梯次利用 10 个，再生利用 15 个，其他标准制定 10 个。其特点是回收网络建设和回收项目多。

在浙江省，由于电池生产企业和储能企业都参与到示范项目中来，因此，以回收网络建设和梯次利用为重点的项目得到了批准。

参与示范项目的企业主要是整车生产企业、电池生产企业、电池材料生产企业以及其他第三方回收的企业。2018 年 9 月，工信部发布了《新能源汽车废弃蓄电池综合利用行业标准条件》。 2021 年 1 月，又有 22 家企业入选第二期满足行业标准条件的企业名单。2018 年发布的第一期满足行业标准条件的企业名单共 5 家：包括华宇钴业、澳鹏科技、格林美、邦普循环、光华科技。同时，2020 年 11 月 12 日，中国电动汽车储能电池梯次利用的相关企业达到 235 家，且每年新进入该业务的企业数量都在增加。这些公司的一个特点是，它们大多是中小型企业。

根据中国电动车智库 EV Tank 的总结，参与电动车电池梯次利用的主要玩家如下：在 EV Tank 看来，目前电池回收利用市场的主要竞争者是整车企业和非电池或电池材料企业的第三方企业，2019 年总份额超过 80%。总市场占有率将超过 80%。未来，电动车电池回收政策的标准将有所提高，龙头企业的竞争优势将更加明显，行业集中度有望进一步提高。

图 4 中国使用回收的企业市场占有率



（资料）EV Tank 汇编而成

作为第三方回收企业，代表企业是邦普循环和格林美。

邦普循环成立于 2005 年，总部位于广东省佛山市，是一家专业从事废旧电池回收和汽车拆解业务的企业，在广东、湖南两省设有生产基地。CATL 于 2016 年 10 月成为最大股东。具备年加工 2 万吨三元电池的能力，年产 1.5 万吨利用回收材料制作三元电池前驱体的业务。 公司在全国拥有 100 个废旧电池回收中心，并与国内外整车生产企业建立了战略合作关系，从事新能源汽车和动力电池的梯次利用和回收。

格林美(GEM)成立于 2001 年，2010 年在深圳证券交易所上市，是中国垃

圾处理和资源回收领域的龙头企业。在 ″电池回收、原材料再制造、材料再制造、电池包再制造、新能源汽车服务提供 ″的生命周期价值链中，与全球 180 多家汽车制造商和电池制造商建立了合作关系。近年来，公司在电子废弃物、废旧汽车和蓄电池的回收利用方面进行了技术研发，取得了 220 多项专利，参与制定了 70 多项国家和行业相关技术标准。年产 10 万吨电动车蓄电池，收集电池企业的废旧电池和废旧材料，可年产 2 万吨电池材料、8000 吨硫酸镍和电解铜。 公司已在全国 20 个城市建立了 2 万个电池回收中心。此外，公司还具备日产 200 个可重复使用电池包的能力，并与比亚迪合作，建设了 4 个使用可重复使用电池的太阳能发电设施。

近年来，通过实施示范工程，建立了覆盖全国的废旧电池收集网络，完善了梯次利用和回收技术,使中国电动车电池再利用产业取得了进展。但是，整个行业仍然面临以下挑战。

· 可回收的电池数量远远小于废弃的数量。存在非法回收的情况，由于盈利问题，合法的收集和使用公司很难回收到电池。

· 由于电池类型的多样性，使得回收过程的兼容性较差。因此，可回收的电池数量和锂的回收率都很低。

· 虽然梯次利用、再循环相关的标准和技术发展有所进步，但在提高标准水平、改进评价技术、提高工作效率等方面的技术仍有欠缺。

- 回收→梯次利用→再回收过程中，降低成本、控制 2 次污染、提高回收率是需要解决的问题。
- 除了从上游到下游全产业链经营的大型企业外，企业的收入模式单一，往往依赖金属在市场上的销售价格，影响了企业的稳定性。

（2）作为社会基础设施的再利用系统

①法律法规·标准的制定

自 2009 年推广新能源汽车以来，工信部等政府部门制定了多项政策。

- 2012 年 7 月，国务院公布《节能与新能源汽车产业发展规划(2012-2020 年)》，建立动力电池回收管理办法，提交制定动力电池回收利用管理办法，促进专业电池回收利用企业发展。
- 2016 年 1 月，工信部等五部门发布《电动汽车动力电池回收利用技术政策》。基本原则是，在动力电池的再利用中，优先考虑梯次利用，如果不能梯次利用，则对动力电池进行回收利用。
- 2016 年 2 月，工信部制定了《新能源汽车废弃电池既有利用行业规范管理暂行办法》和《新能源汽车废弃电池综合利用行业规范和条件》，对动力电池回收利用行业进行规范；
- 12 月，环保部发布《废弃电池污染防治技术政策》。提出了废旧电池

分类、收集、运输、综合利用、贮存、处置全过程的污染防治要求，为废旧电池的环境管理和污染防治提供了技术指导。

- 2017 年 1 月，国务院印发《生产者责任延伸制度推进办法》，指出将全面推进生产者责任延伸制度和电动汽车动力电池回收利用制度，电动汽车生产企业、动力电池生产企业、梯次利用企业和回收拆解企业将承担相应责任。
- 2018 年 3 月，工信部发布《新能源汽车动力电池回收利用测试实施方案》。工信部首次公布了动力蓄电池回收利用试验实施方案，明确了回收的总体目标。2019 年 2 月工信部等四部门发布的《关于加强绿色数据中心建设的指导意见》明确，在满足可靠性要求的前提下，梯次利用动力电池将作为数据中心的储能。

另外，关于锂电池回收及再利用方面，制定了企业准入的管理规定和企业规范条件，以及参与锂电池回收再利用企业的资质要求，提出了企业分布和项目建设条件、规模、设备和技术、资源综合利用和能源消耗、环保、安全等相关要求。

图 5 锂电池材料回收利用的准入管理规则和企业规范条件

2009.07	◆ **《新能源汽车生产企业及产品准入管理规则》**，要求应建立完整销售和售后服务管理体系，包括政策和零部件回收，并有能力实施
2015.03	◆ **《汽车动力蓄电池行业规范条件》**，提出电池企业应同汽车整车企业研究制定可操作的废旧动力蓄电池回收处理再利用方案，为进一步开放准入，该政策已于2019年6月废止
2018.09	◆ **《新能源汽车废旧动力蓄电池综合利用行业规范条件》**，要求从企业布局、规模、装备、工艺、资源利用、能耗和环保等多角度对能源汽车废旧动力蓄电池综合利用企业经行了规范，加强行业管理与回收监管
2018.09	◆ 公布第一批**《新能源汽车废旧动力蓄电池综合利用行业规范条件》**企业名单
2020.01	◆ **《新能源汽车废旧动力蓄电池综合利用行业规范条件（2019年本）》**，明确对新能源电池企业在布局和项目选址、技术装备和工艺、资源综合利用及能耗、环境保护要求、产品质量和职业教育以及安全生产、人身健康和社会责任等方面作出具体解释和原则要求

资料：根据公开信息整理

图 6 锂电池材料回收利用的标准体系

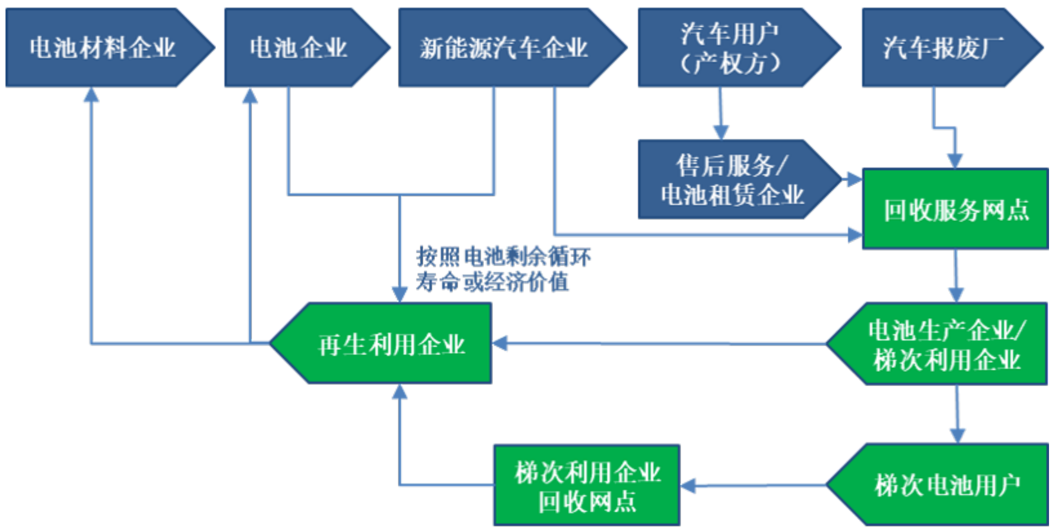
2010.10	◆ 国标委《 GB/T 33059-2016 锂离子电池材料废弃物回收利用的处理方法》
2017.05	◆ 质检总局、国家标准委 《GB/T 33598-2017 车用动力电池回收利用拆解规范》
2017.07	质检总局、国家标准委 ◆《GB/T34014-2017 汽车动力电池编码规则》 ◆《GB/T34015-2017 车用动力电池回收利用——余能检测》 ◆《GB/T34013-2017 电动汽车用动力蓄电池产品规格尺寸》
2019.03	◆ 国标委 《GB/T 37281-2019废铅酸蓄电池回收技术规范》
2019.03	◆ 全国汽车标准化技术委员会 《车用动力电池回收利用 梯次利用产品标识》

资料：根据公开信息整理

②市场的构建

通过 2018 年启动的废旧电池收集利用示范项目，我们试图在全国范围内建立一个锂电池回收利用体系，具体如下。

图 7　锂电池回收与利用系统



（资料）EV Tank 资料

③培养高质量的技术

如上所述，未来中国电动汽车电池的再利用市场将持续增长。近年来，通过示范工程的实施，电动汽车电池的梯次利用和再利用技术有了显著的进步，但要想要高效处理大规模的电池，对环境影响最小，必须提高整个行业的技术水平。

首先，在梯次利用中，电池的安全性评价、废弃电池剩余容量评估、残值性能评价等都没有标准，测量剩余容量和评价残值的技术还不成熟。例如，目前，梯次利用企业经营者往往根据自己的标准对梯次利用电池进行评估，并在与客户的合同中承诺电池的状况。目前需要制订这些标准和诊断技术。

其次，要提高整个行业的自动化率。例如，电动车电池没有标准，每个厂家的形状和尺寸都不一样。 因此，虽然有自动化设施可供梯次利用，但不能处理所有类型的电池，电池组和电池模块的拆解仍常以人工方式进行。需要有技术来降低这些作业的安全性和效率，并减少对环境的负担。

此外，在再生利用中，传统的贵金属提取方式是采用湿法工艺技术，但这种方式对环境造成负担，而且贵金属的回收效率较低。今后，将需要减少环境负担和提高金属回收率的技术。

（3）要求安全和可靠

由于动力电池不仅有镍、钴等贵金属，还有电解液、有机溶剂等有毒有害物质组成，存在环境污染风险。此外，由于电池没有完全放电，无法有效使用，且电压较高，在运输、储存和再使用过程中，极易发生触电和爆炸的危险。

据悉，目前大部分废弃电池由中小企业处理。据中国汽车研究机构估算，2019 年中国废旧电池通过正当渠道回收量只有 10%。未回收的电池由中小型企业通过低成本的人工流程进行拆解和处理，而这些流程并没有得到适当的控制。拆解过程中非法倾倒废液等材料，存在较大的环境污染风险。

今年 5 月，厦门市发生一起车祸，车内发现两吨多的铅酸蓄电池。据说，这些废旧电池被运到另一个城市出售。

2021 年，湖南邦普循环科技有限公司废铝箔储存区发生火灾，造成人员伤亡。这些废铝箔是电池拆解后的废料。

为了解决上述问题，政府正试图从 2019 年开始关注和解决梯次利用相关行业标准的制定和再利用电池追溯体系的建立。据称，特别是要制定快速测量方法和评价与梯次利用有关的剩余价值的标准。此外，据介绍，在避免环境风险、防止污染等环境安全方面，建立动力电池再利用的法规和技术非常必要。

３．电动汽车电池循环经济所需功能

（１）电动汽车电池循环经济的社会发展趋势

目前，实现循环经济，促进电动汽车电池的再利用和回收，正引起人们的关注。促进资源的再利用和循环利用，就可以解决目前的安全问题、资源枯竭问题、二氧化碳减排问题。

如上一节所示，电动车的社会问题包括确保安全和减少非法倾倒的社会负担。目前，电池安装在产品中，其充放电和安全性由电池控制系统(BMS)管

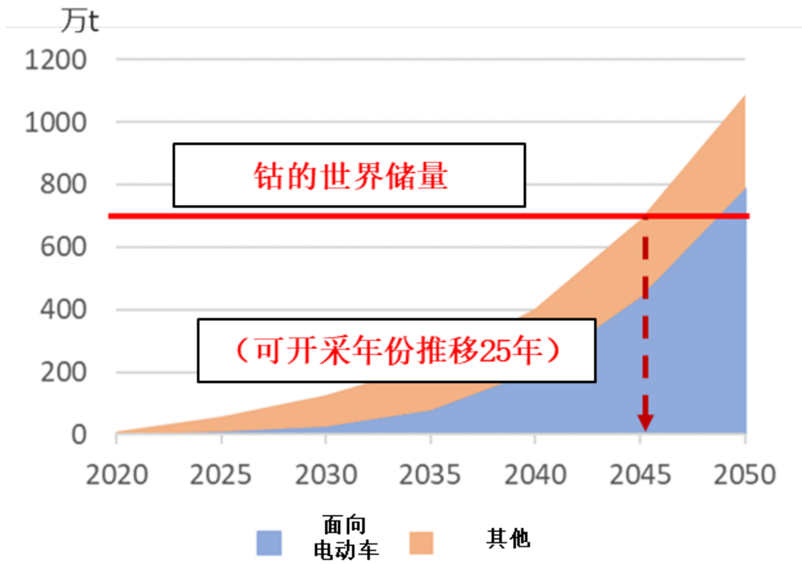
理，但一旦将电池从车上拆下来使用，就无法保证安全。因此，需要维护使用环境，根据电池的使用情况，设置相应的控制系统进行管理。

此外，如果大型电池被非法倾倒，会出现电池中含有的以碳酸酯为主的有机电解液及其他有害物质泄漏等问题。非法倾倒是由于回收管理不当造成的。

循环经济就是通过实现经济上可行的电池循环系统来解决这些问题。

第二个角度是稀有金属等资源的枯竭，随着电动车市场的快速发展，到 2030 年，全球每年消耗钴的数量将超过 100 万吨，20 年增长 25 倍。另一方面，据说目前可开采的钴资源量高达 700 万吨，考虑到电动车市场的扩张，到 2040 年代，资源将面临枯竭的危险，这将导致资源价格大幅上涨等问题。无钴电池的研发也在进步，但要到 2030 年或更晚才会出现，价格飞涨的局面也无法逃脱。为了应对这种情况，循环经济是一种资源循环利用的方式。

图 8 钴矿开采预测



（资料）根据美国地质调查局（2017）及 EV 普及预测等公开资料日本总研整理

三是减少二氧化碳排放的角度。如果电池能够长期重复使用和回收，尽量减少对新资源开采的需求，那么与资源开采和电池制造相关的二氧化碳排放量就可以降到最低。换句话说，易于重复使用和回收的产品将能够作为低二氧化碳排放的产品而与众不同。这将使回收更容易。建立主动回收资源的体系，也有助于减少二氧化碳的排放。 梅赛德斯-奔驰宣布，从 2030 年代开始，将要求其采购的所有零部件都必须是零碳的，预计 2030 年后，不产生二氧化碳的产品将从作为一个显著特征，变成产品销售的强制性要求，循环经

济有望早日实现。

为了打造电动汽车电池的循环经济，欧盟委员会在 2020 年 12 月发布了新的电池管理条例提案。包括电池生命周期中从制造到梯次利用和回收的每个阶段的二氧化碳排放量、碳足迹等重要项目，包括第三方验证机构的证书，以及回收材料的使用量，最早计划在 2024 年实施。 随着这些规定的出台，与欧盟国家有业务往来的企业必须在生产电池的前提下，对电池进行梯次利用和回收，包括标明电池中回收材料的比例，确保可追溯性。过去连溯源性都很难保证，但物联网技术的应用，不仅可以保证溯源性，还可以对车载使用和再利用过程中的安全进行管理，以及高效回收，估计这些规则已经付诸实践。这样一来，电动车电池就成了一种产品，形成了循环经济的一部分，创造了一个新的市场。

图 9　欧盟电池指令(节选)

■在产品设计方面，以下几点等将是电动汽车电池和工业充电电池的强制性规定（条例草案第七

- 碳足迹声明，包括制造商和制造工厂的信息、电池及其生命周期各阶段的二氧化碳(CO2)排放量，以及独立第三方核查机构的认证(2024 年 7 月 1 日起)。
- 指明性能类别，以利于确定整个生命周期(从 2026 年 1 月 1 日开始)的大小二氧化碳排放量。
- 引入整个生命周期的碳足迹上限(自 2027 年 7 月 1 日起)。

■对于含钴、铅、锂、镍的电动车电池、工业电池、汽车蓄电池，以下几点要强制执行(第 8 条)

- 披露这些原材料的再利用数量(自 2027 年 1 月 1 日起)。
- 引入相同原材料再利用的最低百分比(自 2030 年 1 月 1 日起)

（资料）欧洲委员会资料

（2）电动汽车电池循环经济所需的再利用特性

建设循环经济，最重要的功能是实现有效资产的价值最大化。所谓有效资产价值最大化，就是要对作为资产的产品的剩余价值进行适当的评估和分配，最大限度地有效利用。

对于工业产品来说，厂家在生产阶段就要对产品的质量负责。另一方面，很难客观地界定一个产品在使用了一定时间后的价值。传统上，二手市场的价值是由用户的评价决定的。换句话说，当前市场是一种经济制度，在这种制度下，制成品在生产时的价值最容易在社会上分配。

另一方面，在物联网时代，物的历史信息和性能信息将能够体现物的价

值，不仅在作为工业产品销售的时候，而且在作为二手产品销售的阶段，也能够保证价值和可靠性。

这样一来，如果事物的使用价值而不是制造价值被交易，那么经过精心使用的事物的价值就会增加，变得稀少。物联网自动采集的数据将形成社会新的价值基础。这种社会的转型将改变全球以物质为基础的社会。

为了积极应对这些市场变化，必须构建梯次利用市场所需的功能。这就意味着要形成一种物联网机制，用数据的价值代替工业产品和材料的价值进行流通交易。数据可以确保可靠性以及定义价值。例如：施加了多少次冲击，温升超过上限多少倍，进而决定了电池的劣化程度，这些数据决定了电池的价值。由于无法知道电池在使用时的内部状态，我们只能通过估计其内部状态来评估其可靠性和性能。但是，通过收集大量的这种间接数据，可以保证电池质量的概率，实现可靠性。

（3）电动车电池循环经济所需的回收利用功能

另一个功能是使稀缺资源的价值最大化。未来随着电动车的发展，稀缺资源的价格极有可能飙升。如果这样，资源循环利用就有可能自然进行。然而，这是一种乐观的情况，取决于外部环境。一般来说，废弃的资源不容易被分离出来，也不容易转化为资源。这是因为，除非知道它们在哪里以及在

多大程度上含有稀有资源，否则不可能有效地将它们转化为资源。但是，由于过去没有管理这些信息的机制，仅凭经济原则很难回收。为此，迄今为止，回收利用在全球范围内分布，造成了社会问题。

在这样一个外向型的经济体系中，可以消除废物，但不能促进循环利用。那么，应该如何推广回收呢？ 政策之一是建立制度，争取在生产销售时收取回收加工费。日本在 2002 年颁布了《汽车回收法》，建立了用户承担回收费用的制度。这大大减少了国内的非法倾倒现象，同时也促进了催化剂中所含铁、铜、稀有金属的再生利用。

然而，这是一个在物联网时代之前就存在的系统。在物联网时代，可以低成本地保障商品的可追溯性，并根据资源信息提高运输和处理过程的效率和价值。如果能在回收现场掌握资源的物质信息和适当的分离方法，将提高回收的商业潜力；在物联网时代，通过链接产品信息和其他数据，可以揭示材料的价值。

近年来，通过资源循环利用减少二氧化碳排放的价值不断增加，有望进一步提高循环利用的经济效益。

4． 电动车电池循环经济的特点

（1）以电动汽车电池为代表的循环经济建设情况

对电池的循环经济建设寄予厚望。这是因为普通产品的首次利用和再次利用用途往往相同，再次利用时的价值往往大打折扣。

但就电动车电池而言，其首次用途和再次利用用途往往是不同的，因为电动车是需要长距离行驶的车辆，如果一次充电所能行驶的距离减少，产品就不能满足其规格要求。一般来说，电动车在电池剩余容量达到 70-80%时，就到期更换了。换句话说，在汽车等产品通过安装电池自行运行的情况下，驱动能量与安装重量的比值，即能量密度的降低，是直接影响性能的问题。因此，即使电池的残值接近 70-80%，也需要更换。这样一来，EV 电池在完成首次用途的同时，还能保持较高的残值。虽说不能同日而语，但如果将其用于其他用途，特别是用于非移动用途，还是可以长期使用的。

再次利用用途应用的一个典型例子是平衡可再生能源的波动。在日本，零能耗住宅（ZEH）和零能耗建筑正在流行，ZEH 是指通过在屋内安装太阳能等可再生能源，将净能耗降为零的房子。在这种情况下，采用 Eco-Cute 等电热水器和蓄电池来调整太阳能等波动能源与需求之间的不平衡。Eco-Cute 将太阳能的剩余电力转化为热源，用于热水供应，并将多余的电力储存在蓄电池中，供夜间使用。对于未来几十年都要居住的住宅，消费者往往从长远的角度进行资本投资。这样一来，大量的蓄电池需求被创造出来。

超大型太阳能电站和绿色制氢设备也需要大量的蓄电池。这是因为，要使超大型太阳能电站与电网相连，就必须使供需电不至于因云层移动等因素造成电压突然波动而对电网产生不利影响。此外，未来利用太阳能发电的绿色制氢将不断扩大，这里还需要使用蓄电池，以减少负荷波动对制氢设备的影响，降低制氢设备的维护成本。此外，作为城市备灾应急发电的电源，蓄电池的需求也将增加，预计今后储能电池的需求将不断扩大。

电池在未来扩大可再生能源和其他应用方面也将发挥重要作用。为了满足这些日益增长的需求，如第 1 节所示，无法避免有效利用相当于 60 座核电站的供电能力。这些市场有望通过主动应用重复使用的电池而不是引进新的电池，以低成本扩大可再生能源市场。

这样一来，蓄电池可以说是循环经济的优等生，在未来不断扩大的市场中，无论是首次利用还是再次利用都有很高的需求。未来，电动汽车电池作为循环经济的领头羊，将有望在不同的一次和二次应用中得到有效的应用，开发出适合各应用的电池。

（2）促进电池再利用的生态系统

在建设电池的循环经济中，有一个特点与其他电器和其他产品有很大的不同。也就是说，让电池处于带电状态是非常危险的，一定要在适当的管理

下销售、使用、运输。

这意味着电池不应该被当作独立的对象，而必须始终与其管理系统结合使用。换句话说，电池是物联网类的产品，它并不是作为独立的产品，而是作为物联网系统来体现其价值。同时，这意味着买卖电池的实体在使用电池前必须充分考虑数据和管理系统的连接，也意味着系统必须在一个生态系统内共享。接收和使用电池的梯次利用企业也必须能够了解哪些电池在拆解、卸车、运输时处于什么状态。

由于电池的结构，电池不能完全放电到零。这是因为电池的性能明显下降。也就是说，运输和拆解作业是在电池充电到一定程度的情况下进行的。根据电池的充电量、运输过程中处于什么样的温度环境、受到什么样的震动，都会影响到下面的工作。需要建立一个动态的物联网信息联动系统，把电池当成活物来管理，并确保历史信息传递给下一个处理企业。这不仅仅是一个追查电池所有者的问题。这意味着，电池用户构建网络的物联网生态圈，是电池流通市场不可或缺的。

另一方面，这有可能关闭市场，使其成为一个小市场，新的可再生能源供应商和其他公司难以参与市场。 因此，有必要构建一个物联网生态系统的平台，这个平台是开放的，允许人们自由进出，但并不封闭生态系统本身，而是在参与生态系统的同时，可以进行可靠的管理协调。

（３）建设循环经济的挑战

另一方面，如果从目前的市场来看，虽然市场是开放的，但很多企业都是被电池厂商和汽车厂商资本化了。这种情况是不可避免的，因为流通市场才刚刚开始，但这个市场预计到 2030 年将达到 10 万亿日元，不会是一个在几个闭环中高效转动的市场。要想让更多的可再生能源企业、城市管理公司等有效利用这个市场，必须要有一个开放、高效的配电市场。

这样的市场需要一个物联网类的动态信息发布平台，如上一节所述。在这种机制缺失的情况下，目前的情况是，市场在战战兢兢地扩大。构建这样一个系统的关键是：(1)保证投资 (2)实现有关各方的可靠运营。

首先，平台系统从拆解、运输、梯次利用使用、再生利用阶段，涉及的业务范围很广。此外，目前市场还不成熟，能够投资大型平台系统的企业数量有限。 另一方面，汽车制造商和电池制造商也很难实施这种系统。 这是因为，平台运营商要具备物联网市场的管理能力，通过整合商品和信息，整合新的物质资产和无形资产。由于制造业是追求提高商品质量、降低成本的强势企业，所以不具备提高无形资产价值的人力资源。鉴于这种情况，有人认为，要想建立一个面向全中国、面向各地区的平台体系，就必须等待与地方政府合作的新服务商的出现。

其次是市场主体实现可靠运营。目前市场还不成熟，能够开展可靠运营的运营商数量有限。要想在这样的市场中安全高效地拓展业务，发展市场，就必须增加促进可靠经营的经营者，促进发展。一个有效的方法是通过链接这些平台上的信息，实现运营质量的可视化。从电池的验收到拆解等处理，以及使用电池管理系统确保安全等一切信息都必须提供给平台，如果工作质量不好，结果作为数据给下一个操作者看。 换句话说，工作质量低的企业将无法开展业务。这样一来，不提高自身素质的企业将被市场淘汰。

此外，还需要建立一个系统，通过检查运输过程中关键点的电池质量，及早发现和解决问题。目前有多种技术用于测量电池的 SOH 和其他参数的质量。过去只有充放电法的技术，测量一块电池需要 10 多个小时，但近年来，技术的发展，可以在短时间内实现高精度的诊断。但是近年来，能够在短时间内实现高精度诊断的技术已经被开发出来了，这些技术有些是日本的，如果这些技术得到有效的利用，将会大大提高数据发布的可靠性。日本的诊断技术除充放电法外，还有利用放电时的特性、利用充放电曲线的分析法、交流阻抗法、统计法、微 SOH 法、CC-CV 放电法等多种方法。诊断技术大致可分为分析充放电特性的方法和测量内阻的方法。在使用充放电特性时，有多种方法，如分析部分充电特性，或通过重复各种模式的充放电建立电池的模型，而不是像过去那样进行 10 小时的充放电。

为了尽早、简单地检查蓄电池的质量，需要使用符合各类蓄电池特点的诊断技术，因此，选择和使用这些技术要恰当。

５．关于构建电动汽车电池循环经济的建议

在这一节我们讨论电动汽车电池日益增长的市场规模和潜力，以及电动汽车电池形成循环经济的挑战和解决方向。我们认为，只有使传统物质资产的市场和产业结构物联网型，并与无形资产联系起来，才能实现循环经济的建设，需要一个提高可靠性的动态信息发布平台。 因此，我们提出了以下措施来构建这样的体系。

（１）建立开放的市场

首先是建立开放的市场。电动汽车电池由于残值大，电动汽车市场扩大带来的供应量大，以及可再生能源和其他资源利用市场的迅速扩大，即将形成一个对社会有巨大价值的市场。这些新市场将极大地拓展传统旧货市场的边界，形成新的循环经济市场。这个市场与普通汽车企业的规模相比将是足够大的，它将是一个回报社会的巨大价值的市场。而在一个封闭的市场中，每个汽车企业只要负责自己企业的回收利用，这无法遏制不法流通。

因此，我们建议形成一个开放的市场，而不是汽车厂商和电池厂商直接交易的封闭市场。为此，应建立数据联动平台，使汽车制造商和其他负责管理电池的企业能够安全地进行外包加工，确保未来循环型社会的资源回收。该平台将是一个数据联动系统，在地方政府的参与下，确保保密数据的可靠性和确定性，确保相关数据和电池的控制状态传递给企业。 此外，未来可能会有各种玩家进入这些市场。即使是新的操作员也必须能够可靠地处理数据。

（2）与日本合作推进品质管理

二是在质量控制方法和梯次利用/再循环技术方面与日本合作。日本领先于其他国家开发了各种诊断技术来控制电池的质量。为了利用这些诊断技术及其数据，与拥有这些技术的日本企业合作是非常有效的。

电池有磷酸铁、三元等几种类型，还有每个公司特有的制造方法和电池的大小，所以不能单独使用一种诊断技术。因此，要根据蓄电池的类型，做好多种诊断技术。在日本，以日本总研为首的多家诊断技术公司正在共同开发相关技术。

此外，日本已经形成了一套可以作为参考的细致梯次利用和再生利用体系。虽然电动车用大型电池还没有开始流通，但近百家拆解、再利用、回收、运输行业的企业正共同致力于优质二手汽车零部件的运输和销售。在那里，

零件会被小心翼翼地拆除，以确保拆解过程中的环保性，并对产品的任何损坏或褪色进行拍照，以便能够清晰地识别，并实现信息共享。与新产品不同的是，二手零件会发生各种类型的变质，但如果不清楚变质的地点和方式，就无法通过网络服务购买大范围内产生的回收零件。为此，公司通过最大限度地披露降级信息，确保信任，不利于产品销售。 此外，在确保信任方面，如果销售产品的公司进行不恰当的处理，不仅会降低该公司的信任度，还会降低整个网络的信任度，所以公司积极努力提高运营质量，分享其理念。

在中国也是如此，预计将积极使用能够明确电池质量的诊断技术，建立明确质量的机制，促进废旧电池的使用。但是，在这些废旧零部件的流通过程中，不仅要发布信息，还要提高产生和发布这些信息的企业本身的可靠性，在这种信任的基础上，形成电动汽车电池越来越多的再利用市场。基于物联网的信息管理离不开诊断技术和方法，提高这些企业的可靠性。预计与在这方面有良好业绩的日本合作，将促进市场健康发展。

（3）市场形成的制度设计

三是制度设计，形成完善的新市场。循环经济是一种社会基础设施，它不仅通过再利用、再循环促进市场的形成，而且有利于提高整个社会的安全性、环境价值、资源节约和低碳化。从这个意义上讲，要促进市场的形成，

政府要给予适当的支持。

特别是电池属于危险品，如果仅仅依靠市场的力量，人们担心在运输和储存方面偷工减料、管理不到位的企业会继续增加。特别是考虑到今后电动车市场将不断扩大，要积极发展和扩大能够妥善处置的企业数量。在这种情况下，如果前期引进管理设备和系统，市场效率会提高，电池的巨大剩余价值会导致新的市场进入者增多，可望发展成规模化市场。但是，在市场初期，企业自身投资开发信息管理系统的负担很重。有鉴于此，希望政府将实施以下措施，作为其制度设计的一部分。

① 对非法倾倒垃圾，造成环境污染等行为进行严格的处罚，并通过建立制度进行分配控制，确保垃圾的可追溯性。如果我们不能严厉打击非法外流的废物和国内市场不适当的廉价流通，其背后的非法倾倒就不会消失。这是一个已经存在的系统，但作为利用该地区电动汽车电池信息联动系统的系统，有望在质量上进一步提高。

② 与日本一样，汽车购买者要额外支付汽车回收费用，由政府管理，在车辆拆解回收时再支付给相应的公司作为回收费用。这一制度的基础是确保可追溯性。如果能做到这一点，就可以避免不当的废物流向海外。

③ 除了对市场初期进行高质量管理的企业给予补贴，以支付引进系统的费用和其他费用外，我们还将对引进基于物联网的信息管理系统，能够实

现一定程度的质量控制的企业颁发营业执照，并促进对不符合标准的企业进行打击。这种制度的出台，可以保证更多的新企业进入市场，并且能够获得政策资金的支持，保证高质量的控制，从而促进循环市场的发展。在市场形成初期，需要政府提供这样的资金，一旦发展了一定数量的经营者，就可以在没有政府支持的情况下独立经营，通过市场拓展提高效率，增加经营活力。

目前，市场处于起步阶段，几大运营商纷纷成长起来。然而，目前仍然很少有公司推出可靠的高质量电池管理技术和系统。正是在这个市场的初期，为了市场化需要采取新的措施。。

（4）形成以循环利用为基础的新型产业结构

如上所述，电池的循环经济将是形成品牌价值、知识产权等无形资产经济与物质资产经济相结合的市场的起点。

在循环经济中，质量不能像传统的单体产品那样同质化。因为要将相同但价值不同的产品逐一流通交易。为此，将产品的履历、特点分析、现状等信息进行组合和发布，为满足用户需求的产品创造价值。换句话说，在循环经济中，不仅形成了一次使用价值，还形成了二次使用的市场，即与各种无形资产价值相联系的商品和信息的融合。

传统上，产品的生产主要是为了满足其主要用途。二次利用只是产业结构外的附加的小市场。但对于电动车电池等产品来说，二次使用的价值占产品价值的很大一部分，流通市场的价值就显得非常重要，产品价值不再仅仅由一次使用的价值决定。例如，当再利用电池用于调节风力发电的波动时，跟踪能力强、充放电特性均匀的电池在二次使用阶段将受到高度重视。这样的电池具有很高的二次使用价值，交易价格很高，在制造产品时就将电池的二次使用价值纳入汽车评价。换句话说，电池将成为汽车一次使用市场和可再生能源二次使用市场的结合市场的产品。此外，二次利用市场将是过去难以处理的集商品和信息于一体的无形资产增加的市场。这样一来，汽车市场和可再生能源市场将形成一个新的模块化产业结构，在这个结构中，物联网将以电池这个核心部件为中心的复杂市场联系起来。

从历史上看，在美国底特律以汽车等最终工业产品为中心的传统产业金字塔结构发展之后，以深圳为中心的消费电子、智能手机、机器人等产业结构模块化生态圈遍地开花。这种新的产业结构转型，将诞生以具有嵌入式无形资产价值的元器件为中心的多产业物联网模块化生态系统。

过去，中国已成功打造了机器人产业、智能手机等物联网类产品产业。希望最大限度地利用这些知识，促进循环经济新产业结构的形成。

Building a Circular Economy for EV Batteries

The Japan Research Institute, Limited

1. Expansion of Battery Market in the EV Era

(1)Global EV Trend

In 2009, Mitsubishi Motors launched "i-MiEV" as the world's first mass-produced EV, and in 2010, Nissan Motor Co., Ltd., also a Japanese company, launched "leaf", which led to the introduction of EVs in the general market. Although the spread of EVs was expected due to their high environmental friendliness, since EVs have lower profit margins than gasoline-powered vehicles, movements of major manufacturers on a global scale have not been active since then, and they did not spread until the mid-2010s.

China was the first country in the world to popularize EVs. Beginning in 2010, China introduced the so-called "10 cities 1000 EVs" policy, which resulted in the introduction of the system in cities across the country. Since 2013, China has provided large-scale subsidies to promote introducing of EVs among a large number of people, including ordinary households. In addition to subsidies, the government is also promoting the development of an environment for the spread of

EVs by implementing preferential policies for EVs and other vehicles under license plate regulations and policies to support the development of charging infrastructure. By combining these policies, China accounted for the majority of EV sales in the world in 2018.

In response to the expansion of EVs in the Chinese market, Chinese automakers have been active in the production of new-energy vehicles, and from around 2019, European and American brands, which place particular emphasis on the Chinese market, began to gradually shift to EVs. For example, Volkswagen of Germany declared the production of 22 million EVs by 2028, and 40% of new car sales will be EV by 2030. By 2025, GM of the U.S. will produce all 30 typies of EV, and all new cars will be EV or PHV by 2035. Volvo of Sweden, which is affiliated with Jili Motor, is the most aggressive, and it says that 50% of new cars will be EV by 2025 and 100% by 2030. In this way, each manufacturer is now in a position to set specific numerical targets.

Figure 1: Target of EV introduction in each country

Produced by JRI base on various sources

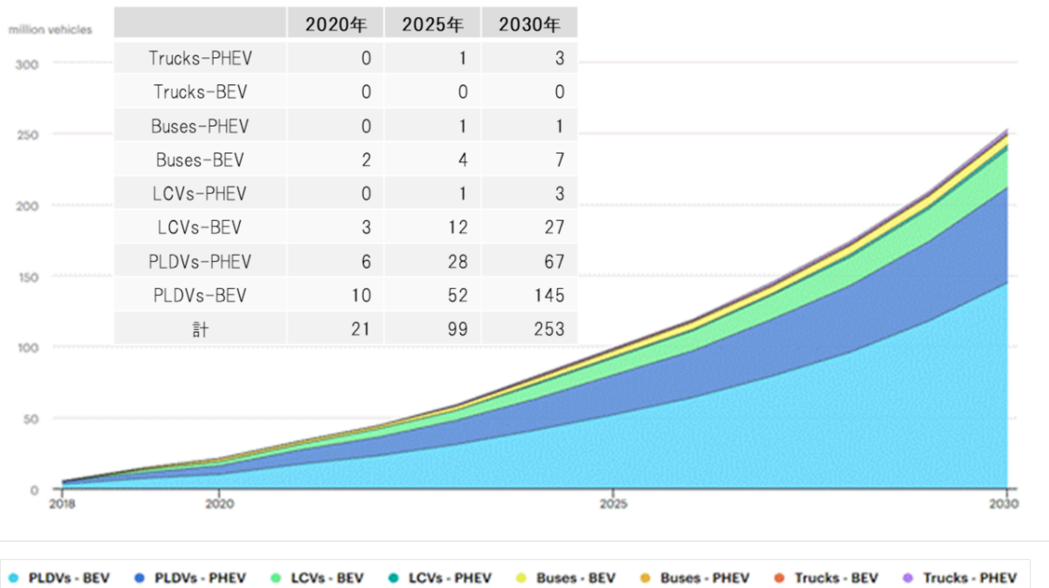
In 2020, European governments began setting targets for the proportion of electric vehicles in their domestic markets. Germany and UK have declared policies of banning the sale of gasoline-powered vehicles (Including diesel vehicles. hereinafter the same) by 2030, Germany will ban the sale of PHVs in 2030 and UK will ban the sale of PHVs in 2035. France will ban the sale of gasoline vehicles in 2040. Norway has the most avant-garde goal, banning the sale of PHVs as well as gasoline-powered vehicles by 2025. Such numerical targets were set by European countries around 2015, but at that time, there were no actual EVs to be sold, so the feasibility of such targets was being tested from the beginning. The target seems to be realistic to a certain extent, partly because manufacturers are making progress in dealing with the problem.

In October 2020, the China Society of Automotive Engineers presented a "Roadmap for New Energy Vehicle Technology" outlining the outlook for future targets in China until 2035. According to the roadmap, hybrid vehicles will be 50% in 2035, and the remaining 50% will be EV or PHV, so it is planned that there will be no gasoline-powered vehicles. The ratio of EVs to PHVs in China is currently around 4: 1, and it is expected that the ratio will remain at this level or increase further in the future.

Based on the policies of the governments of China and European countries as well as the moves of major manufacturers, the IEA (International Energy Agency) has indicated that it expects the spread of new-energy vehicles. According to the report, EVs are expected to increase greatly in the 2020s, and the number of EVs in operation as of 2020 was about 12 million, but will increase to 179 million by 2030.

China is the driving force behind such EV growth, followed by Europe. This picture will remain unchanged throughout the 2020s, and trends in the Chinese market will be important in shaping the EV-related market.

Figure 2: Estimated Number of EVs Introduced in the World



	2020年	2025年	2030年
Trucks-PHEV	0	1	3
Trucks-BEV	0	0	0
Buses-PHEV	0	1	1
Buses-BEV	2	4	7
LCVs-PHEV	0	1	3
LCVs-BEV	3	12	27
PLDVs-PHEV	6	28	67
PLDVs-BEV	10	52	145
計	21	99	253

IEA " Global EV Outlook 2020 "

In 2030, if 179 million EVs run as predicted by the IEA, assuming a replacement period of 5 years, 36 million EVs will be sold globally every year.

On the other hand, new car sales in China are estimated to increase from around 26 million at present to around 30 million in 2030 (Although there is a possibility of further growth, the figure of 30 million units, which is highly feasible, is assumed here.). As mentioned above, 50% of automobile sales are new energy vehicle and 80% of them are EVs, so the number of EVs sold in 2030 will be 12 million. The Chinese market is expected to account for about 1/3 of total global EV sales. Although it will be lower than the current 50%, the Chinese market will be the driving force of EV sales throughout the 2020s.

(2)Large Amount of Used Batteries

As EVs spread on a large scale, the size of on-board batteries will also increase. Major battery manufacturers have been investing heavily in production expansion over the past few years, including CATL, the world's largest manufacturer, which has said it will increase its production capacity from 36 GWh to 115 GWh. It is also expected that the scale of the EV market will expand further in the 2020s.

Some EVs are used as used cars several times before being disposed of after certain period of time. Therefore, when EV is dismantled after disposal, the on-board battery is removed from the vehicle body and becomes a used battery. In the future, automotive batteries are expected to be used in a life cycle that is different from the product life of EVs themselves, as evidenced by the ongoing trend of electric vehicle separation and BaaS mainly in China.

Here, I would like to summarize the capacity scale of the in-vehicle battery that is separated from the EV body and reused. Despite some progress in BaaS, the scale as of 2030 is estimated using a simple model. The capacity scale of reusable batteries is obtained by multiplying the number of used batteries by the capacity per used battery.

First, the number of used batteries. Assuming a simple model (The period until disposal is the same as the replacement period: 5 years, from 2020 to 2030, the market grows linearly), the number of EVs discarded in 2025 is estimated to be 2.52 million globally, 1.36 million in China, and 19.25 million globally and 6.68 million in China 2030.

Next, the capacity per used battery. It is estimated that the capacity of batteries in EVs will become polarized in the future. That is to say, while the battery installed in the vehicles of the category where the cruising range such as the premium brand is required becomes larger, the battery of the vehicles specialized in the driving in the region becomes smaller. At present, batteries with capacity of approximately 40 kWh per EV are installed, but larger batteries will be installed with a capacity of approximately 80 kWh, while smaller batteries will be installed with a capacity of less than 10 kWh. Therefore, the average value is assumed to be 40 kWh. In addition, it is assumed that the storage capacity of a used battery is reduced by about 20% from new battery, and is about 32 kWh per battery.

Based on the above, the estimated capacity of automotive batteries for reuse in 2025 was 80.6 GWh globally and 43.5 GWh in China, and in 2030 it was 616.3 GWh globally and 213.8 GWh in China. Assuming that the market size is 50,000 yen per kWh, the market size in China alone is about 10 trillion yen.

Reusable batteries are especially expected to be used as ESS, and they are expected to last for about five years after being used. Based on this assumption, the cumulative reused battery capacity in 2030 was estimated to be 1742.4 GWh globally and 643.2 GWh in China. This means that China alone has the capacity of about 60 nuclear power plants, when calculated as the power supply capacity when discharging electricity simultaneously from EVs.

There are two types of onboard batteries: lithium-iron phosphate batteries and ternary lithium-ion batteries. In the future, as the ratio of ternary batteries increases, they will be segregated according to the attributes of EVs to be mounted, and it is assumed that both will coexist. The ternary system contains a large amount of rare metals, so there is a tendency to recycle it. However, it is considered reasonable to reuse it in ESS, etc. in any case, if economic value in the life cycle is sought.

Figure 3: Trends in the Size of Reused EV Batteries

EV Sales Volume (10,000unit)

	2020年	2025年	2030年
World	252	1926	3600
China	136	668	1200

EV discardes Volume (10,000unit)

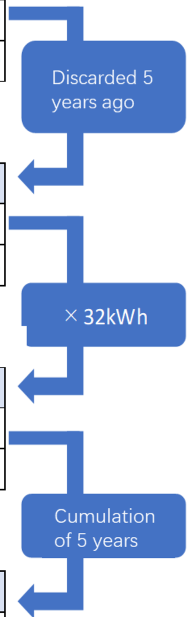
	2020年	2025年	2030年
World	60	252	1926
China	33	136	668

Capacity scale of reuse Bettery(GWh)

	2020年	2025年	2030年
World	19.2	80.64	616.32
China	10.6	43.52	213.76

Cumulative scale of reuse Bettery(GWh)

	2020年	2025年	2030年
World	—	249.6	1742.4
China	—	135.2	643.2



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2. Reuse and Recycle of EV Batteries

(1)Trends in EV Battery Reuse and Recycly

According to statistics from Chinese industry associations, in 2018 and 2019 China's waste batteries accounted for 6.2 GWh and 15.33 GWh. Before 2016, manyEV used lithium-iron phosphate batteries because of large-scale of buses and distribution vehicles. In the initial stage, most of the reused batteries are lithium-iron phosphate batteries, but the number of ternary lithium-ion batteries will increase in the future.

Since 2009, the Chinese government has been advocating the establishment of system to collect and reuse of batteries, while promoting the dissemination of EV. In 2016, Chinese government announced a policy to expand production responsibility, fully implement the construction of a system for reusing electric vehicle batteries, and clarify the recycling responsibility of automobile manufacturers. Furthermore, in May 2018, Ministry of Industry and Information Technology and other government agencies announced the "Notice of model project for Reuse and Recycle of EV battery", which led to the start of model projects for the collection and reuse of EV battery nationalwide mainly led by local governments.

Since May 2018, 18 areas including Beijing, Tianjin, Hebei Province, Guangdong Province, Shenzhen City, Zhejiang Province, Ganso Province, Jiangsu Province, Henan Province, Hubei Province, Qinghai Province, Fujian Province, Jiangxi Province, Anhui Province, and Shanxi Province have been selected as model project areas.

These regions have developed regional versions of "Implementation plan of model project for Reuse and Recycle of EV battery" and are demonstrating technology and business models in such areas as waste battery collection networks, cascade utilization, and dismantling and recycling, as well as fostering representative companies.

The characteristics of the model project in each region are based on the characteristics of the region or the characteristics of the representative company in the region.

For example, in Beijing, Tianjin, and Hebei provinces, 21 model projects proposed by 18 recycling companies were approved. Of these, three were for collection networks, nine for reuse, three for disassembly, and one for recycling. It can be seen from the fact that reuse is common. A well-balanced selection of recovery networks, reuse, dismantling, and recycling businesses was made.

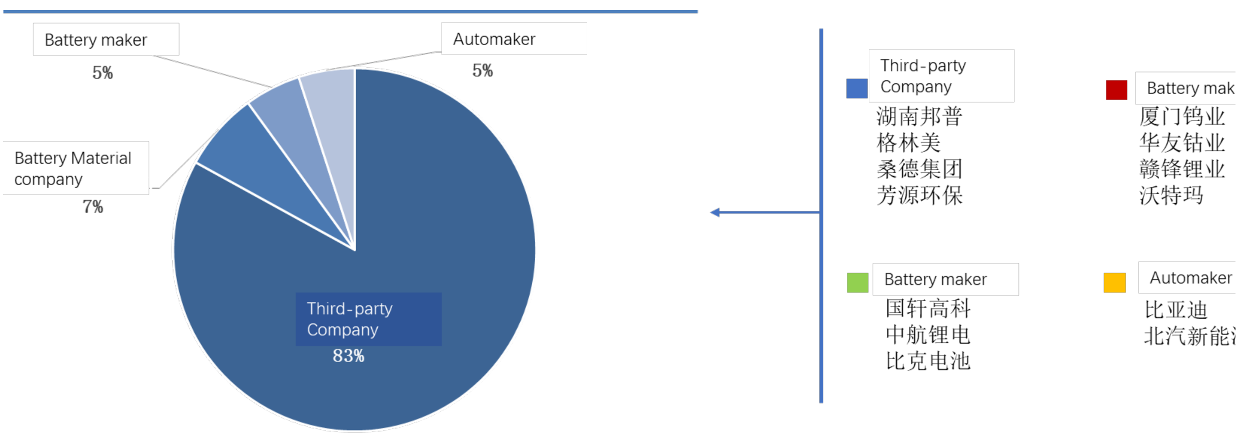
In Hunan province, many recycling businesses were chosen because the main businesses are material recovery companies. Of the 45 model projects that have been approved, 16 have been established as collection networks, 10 have been reused, 15 have been recycled, and 10 have been established as other standards. It is characterized by many recovery network construction and recycling business.

In Zhejiang Province, battery manufacturer and energy storage company are involved in a model project, so the project focusing on the construction of a recovery network and reuse was approved.

The companies involved in the model project are mainly manufacturers of AUTOMAKERS, battery manufacturers, battery material manufacturers, and other third-party companies that collect and reuse batteries. In September 2018, Ministry of Industry and Information Technology announced the "Industry Standard Conditions for Comprehensive Use of Waste Batteries fromEV". Five companies, Cobalt Industry Co., Ltd., Goho Technology Co., Ltd., Kyokurin Bei Co., Ltd., Boppu Circulation Co., Ltd., and Koka Technology Co., Ltd., were selected to fit the these standards. In January 2021, additional 22 companies were selected to fit these standards. In addition, there are many other companies that have been recognized as model enterprises by local governments. On November 12, 2020, the number of companies involved in the reuse of EV batteries in China reached 235, and the number of new companies entering the business has been increasing year by year. It is characterized by a large number of SMEs.

According to the report of EV tanks, an EV related think tank in China, main players involved in the reuse of EV batteries are as following. Currently, main competitors in the reuse/recycle battery market are third-party companies that collect and reuse batteries, with combined share of more than 80% in 2019. In the future, the standards for EV battery reuse policy will be improved, and the competitive advantage of major companies will become clearer, and the degree of industry concentration will be further improved.

Chart 4: Market share of recyclers in China



EV Tank report

The leading third party reuse/recycle companies are Bangpu Circulation Co., Ltd. and Gelinmei Co., Ltd.

Founded in 2005 and headquartered in Foshan, Guangdong Province, the company specializes in battery recycling and vehicle dismantling. There are production bases in Guangdong Province and Hunan Province. CATL became the largest shareholder in October 2016. The processing capacity of the ternary battery is 20,000 tons per year, and the annual production capacity of the business of producing the precursor of the ternary battery from recycled materials is 15000 tons. There are 100 waste battery collection centers in china, and they have formed strategic cooperative relations with domestic and overseas finished car manufacturers to carry out cascade utilization and recycling of new-energy vehicles and power batteries.

Gelinmei, established in 2001 and listed on the Shenzhen Stock Exchange in 2010, is a leading company in the field of waste management and resource recycling in China. The company says it has established cooperative battery collection relationships with more than 180 automakers and battery manufacturers around the world over a series of lifecycle value chains with "Recovery of batteries, remanufacturing of raw materials, remanufacturing of materials, remanufacturing of battery packs, and provision of services forEV". In recent years, the company has been involved in the development of technologies for the recycling of electronic waste, waste vehicles, and storage batteries, has acquired more than 220 patents, and is involved in the development of more than 70 national and industry technical standards. It has an annual EV storage battery processing capacity of 100,000 tons, and can recover waste batteries and waste materials from battery companies to produce 20,000 tons of battery materials, and 8000 tons of nickel sulfate and electrolytic copper annually. In 20 cities in Japan, 20,000 battery recovery centers have been constructed. It is also capable of producing 200 reusable packs per day, and in partnership with BYD, has built 4 solar power generation facilities that make use of reusable batteries.

In recent years, through the implementation of model projects, a nationwide waste battery collection network has been established, and technical capabilities for reuse and recycling have been improved, and the recycling industry of EV batteries in China has made progress. However, the industry as a whole still faces the following challenges.

- The amount collection volume is much less than the amount volume of dispose. Illegal collection and recycling is exist, and it is difficult for authorized collection company to collect batteries due to the problem of profitability.
- There are various types of batteries and the compatibility of recycling treatment is low. Therefore, the amount of battery that can be reused and the reuse rate of lithium are low.
- Although standards and technologies related to reuse and recycling have been

developed, there are still insufficient technologies to improve the standard level, evaluation technologies, and efficiency.

- Reduction of costs, control of secondary pollution, and improvement of recycling rate are issues in the process of recovery, reuse, and recycling.
- Exception of large companies operating in all industrial chains from upstream to downstream, companies have a single profit model and tend to depend on the selling price of metals in the market, which affects business stability.

(2)Reuse System As Social Infrastructure

① Establishment of legal regulations and standards

Since 2009, the government departments such as Ministry of Commerce, Ministry of Industry and Information Technology have formulated various policies to promote the use ofEV.

- In the "Energy Conservation and New Energy Vehicle Industry Development Plan (2012 – 2020)" announced by the State Council in July 2012, EV battery Reuse and recycle management methods will be established, and the development of EV battery Reuse and recycle management methods will be submitted to promote the development of specialized battery recovery companies.
- In January, 2016, 5 divisions including the engineering department

announced "Technology Policy for Reuse and recycle of EV Batteries". In the Reuse and recycle of batteries, the basic principle was shown that the use of cascade utilization was given priority, and the recycling was applied when cascade utilization was not available.

- In February 2016, Ministry of Industry and Information Technology established the "Temporary management method for new energy vehicle waste battery starting use industry standard" and the "Standard conditions for new energy vehicle waste storage and integrated use industry" to regulate the EV bettery recycling industry.
- In December, the Ministry of Environmental Protection announced "Waste battery pollution prevention technology policy". This paper presents the requirements for pollution prevention of all processes of waste battery classification, collection, transportation, Reuse and recycle, storage and disposal, and technical guidance for environmental management and pollution prevention of waste battery.
- In the "Proposal for promotion of manufacture responsibility expansion system" announced by the State Council in January 2017, it was announced that the producer responsibility expansion system and collection and Reuse and recycle system of EV batteries would be fully promoted, and that AUTOMAKERS, battery companies, cascade

utilization companies, and reuse and dismantling companies would be held responsible.

- In March, 2018, the Ministry of Engineering and Communication announced "Trial point implementation plan for reuse and recycle of batteries for EV". For the first time, the company announced a plan for conducting tests on the Reuse and recycle of betteries and clarified the overall goal of recovery. In the "Guidance on strengthening the construction of green data centers" announced in February 2019 by 4 divisions including the Engineering Department, it was clarified that cascad use battery can be an energy storage for data center based on satisfing reliability requirements.

In addition, regarding the Reuse and recycle of EV batteries, regulations and normative conditions for the entry of companies, and qualification requirements for entrants were established, and requirements related to the distribution of companies and project construction conditions, scale, facilities and technology, integrated use of resources and energy consumption, environmental protection, safety, etc. were presented.

Chart 5: Entry Management Rules and Corporate Standard Conditions for the

Reuse and recycle of Lithium Battery Materials

2009.7	◆ New Energy Vehicle Manufacturing Enterprise and Product Entry Management Rules, which require that a complete sales and after-sales service management system should be established, including policies and parts recycling, and the ability to implement
2015.3	◆ The automotive power battery industry regulatory conditions, proposed that battery companies should work with automotive enterprises to study and develop an operable recycling program for the treatment and reuse of used power batteries, in order to further open access, the policy has been repealed in June 2019
2018.9	◆ The new energy vehicle waste power battery comprehensive utilization industry specification conditions", requirements from the enterprise layout, scale, equipment, process, resource utilization, energy consumption and environmental protection and other multi-perspective on the energy vehicle waste power battery comprehensive utilization enterprises have been regulated to strengthen industry management and recycling supervision
2018.9	◆ Announced the first batch of "comprehensive utilization of new energy vehicle waste power battery industry specification conditions" enterprise list
2020.1	◆ The New Energy Vehicle Waste Power Battery Comprehensive Utilization Industry Specification Conditions (2019), which clearly explain and principle requirements for new energy battery enterprises in terms of layout and project location, technical equipment and processes, comprehensive utilization of resources and energy consumption, environmental protection requirements, product quality and vocational education, as well as safety production, personal health and social responsibility

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Chart 6: Standard System for Recovery and Utilization of Lithium Battery Materials

2010. 10	◆ GB/T 33059-2016 Treatment of lithium-ion battery material waste recycling by the National Standards Committee
2017. 5	◆ GeneralAdministration of Quality Supervision, Inspection and Quarantine, National Standards Committee "GB/T 33598-2017 vehicle power battery recycling dismantling specifications
2017.7	General Administration of Quality Supervision, Inspection and Quarantine, National Standards Committee ◆ GB/T34014-2017 Automotive Power Battery Coding Rules ◆ GB/T34015-2017 Power Battery Recycling for Vehicles - Residual Energy Testing ◆ GB/T34013-2017 Power Battery Product Specification Dimensions for Electric Vehicles
2019.3	◆ GB/T 37281-2019 Technical Specification for Waste Lead-Acid Battery Recycling
2019.3	◆ National Automotive Standardization Technical Committee "Automotive Power Battery Recycling Cascade Utilization Product Marking

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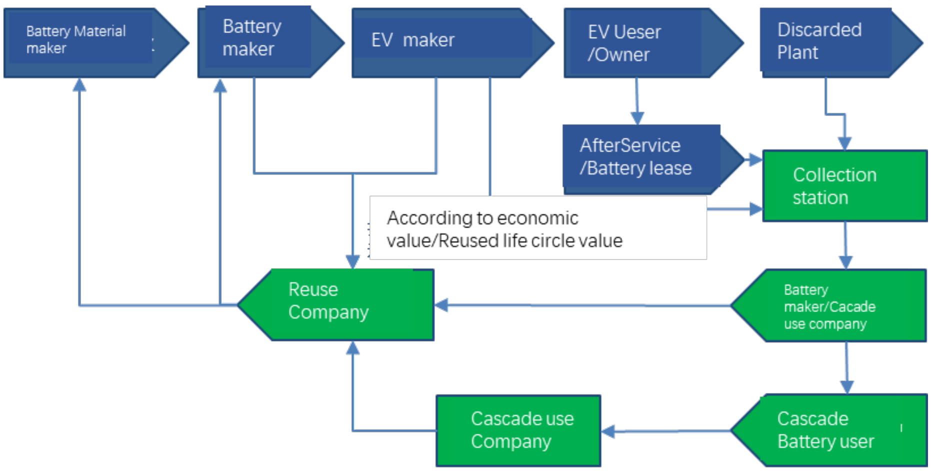
② market building

As described below, the company is trying to establish a nationwide EV battery reuse and recycle system through the model project starting from 2018.

Figure 7: Lithium Battery Reuse and recycle System



EV Tank Report

③ Development of high-quality Technologies

As mentioned above, the reuse and recycle market for EV batteries in China will continue to expand. In recent years, through the implementation of model projects, technological progress has been made in the cascade utilization and recycling. However, in order to process large-scale batteries efficiently and with less environmental impact, the technological level of the entire industry must be raised.

For reuse, there are no standards for evaluating the safety of batteries, evaluating the remaining amount of waste batteries. Moreover, technologies for measuring the remaining amount of batteries and evaluating residual value are not yet mature. For example, companies currently engaged in reuse business often evaluate reusable batteries based on their own standards and promise the condition of the batteries in a contract with customer. Improvement of these standards and development of diagnostic techniques are required.

Second, we need to increase the automation rate across the industry. For example, there is no standard for EV batteries, and each manufacturer has its own shape and size. Therefore, in the case of reuse, although automated equipment is available, it cannot be applied to all batteries, and the dismantling of battery packs and modules is still often performed manually. There is a need for technology that reduces the safety, efficiency and environmental burden of such work.

For recycle, precious metals have traditionally been removed by wet treatment technology, but this has a high environmental burden and low extraction efficiency. Technologies with low environmental impact and high metal extraction rate are required in the future.

(3)Safety and Reliability Required

EV betteries are made of precious metals such as nickel and cobalt, as well as toxic and harmful substances such as electrolytes and organic solvents, which pose risk of environmental pollution. In order to effectively reuse the battery, it does not discharge completely and the voltage is high, so there is a high risk of electric shock or explosion during transportation, storage and reuse.

Currently, it is said that most of the discarded batteries are handled by small and medium-sized companies. According to an estimate by a Chinese automobile-related research institute, the amount of waste batteries collected through formal compaonies in China was only about 10% in 2019. Most of batteries were collected and disassembled, disposed of by small and medium-sized companies, which are poorly managed, low-cost manual processes. There is a high risk of environmental pollution due to illegal dumping of waste fluids during dismantling.

In May 2020, more than two tons of lead acid batteries were found in a car accident in Xiamen. The aim is to transport the batteries to other cities for sale.

In 2021, a fire broke out by aluminum foil at storage area where EV batteries are dismantled and discarded at Hunan Provincial Circulation Technology Corporation, which causing casualties.

In order to solve the above problems, the government has been making efforts since 2019 to establish industry standards for reuse and a trace system for EV batteries. In particular, it is said that establishing standards for rapid measurement and evaluation of reuse-related residual values is important. In the reuse of EV betteries, it is considered essential to establish regulations and technologies concerning environmental safety, such as avoiding environmental risks and preventing pollution.

3. Functions Required for the Circular Economy of EV Batteries

(1)Social Trends in Circular Economy of EV Batteries

Currently, attention is focused on the realization of a circular economy that properly promotes the reuse and recycling of EV batteries. Reuse and recycling of resources can solve the problems of safety, resource depletion and CO2 emission reduction that we face today.

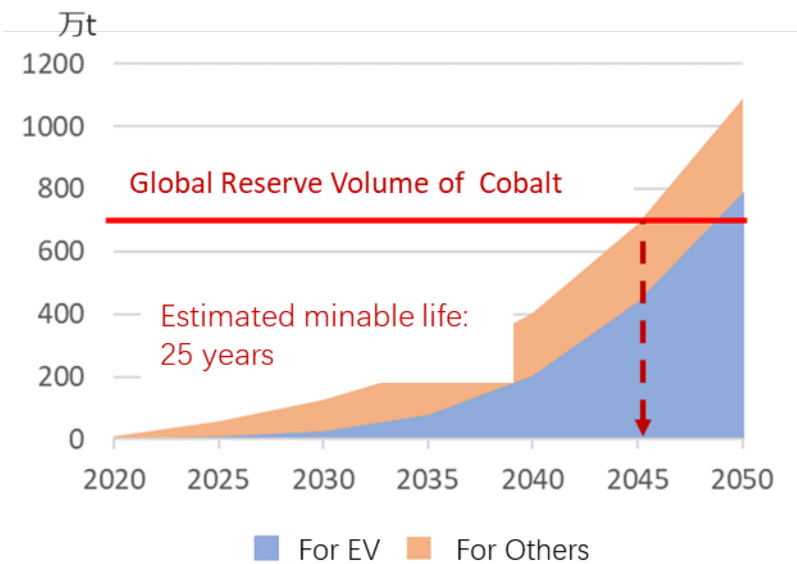
As mentioned in the previous section, the social issues of EVs include ensuring safety and reducing social burdens such as illegal dumping. At present, batteries are installed in the product, and charge/discharge and safety are controlled by the battery control system (BMS), but if batteries are removed from the vehicle and used, there is no means to ensure safety. Therefore, it is necessary to improve the usage environment and to establish and manage an appropriate control system according to the usage of the battery.

In addition, if a large battery is illegally dumped, the carbonate ester, which is a dangerous substance contained in the battery, mainly leaks out of an organic electrolyte. Illegal dumping is caused by improper management of recycling.

As a means to solve these problems, the circular economy is to realize an economically viable battery circulation mechanism.

The second viewpoint is the depletion of resources such as rare metals. With the rapid growth of the EV market, in 2030 the world will consume more than 1 million tons of cobalt per year. In 20 years, the number is expected to increase 25 times. At present, the maximum amount of cobalt resources that can be mined is said to be 7 million tons. Considering the expansion of the EV market, in the 2040s, there will be a crisis of resource depletion, and issues such as rising resource prices will arise. Although the development of cobalt-free batteries is progressing, they will not be released on the market until 2030, and the price will inevitably rise. In order to cope with this situation, circular economy is to recycle resources.

Chart 8: Prediction of cobalt mining trends



Compiled by the Japan Research Institute from the U.S. Geological Survey (2017)

The third is the viewpoint of CO2 emission reduction. If batteries are reused for a long time and recycled to minimize the extraction of new resources, CO2 emissions from resource extraction and battery manufacturing can be minimized. In other words, products that are easy to reuse and recycle will be differentiated from products that emit less CO2 in the future. This will make recycling easier. By establishing a system that actively recycles resources, we can also contribute to the reduction of CO2 emissions. Benz announced zero-carbon requirement for all parts it procures from 2030s. Products that do not emit CO2 are expected to become essential requirements for the sale of products after 2030 from the view point of differentiatio . We expect Early realization of circular economy.

From this perspective, the European Commission announced a new battery management rule in December 2020 to create a circular economy for EV batteries. These include important items such as CO2 emissions at each stage of the battery life cycle, from manufacturing to reuse and recycling, carbon footprints such as certificates from third-party verification organizations, and specification of the amount of recycled materials used. The earliest of these items is scheduled to take effect in 2024. As a result of these regulations, companies that do business with EU countries are now required to manufacture batteries on the assumption that they will be reused or recycled, for example, by indicating the ratio of recycled materials in batteries and ensuring traceability. In the past, it was difficult even to secure traceability, but it is assumed that these rules have been put into practice because the recent use of the IoT has enabled not only traceability but also safety management during vehicle loading and reuse, and highly efficient recycling. In this way, EV batteries have created a new market as a product that forms circular economy.

Chart 9: EU Battery Directive (excerpt)

■In the product design, the following points are required for EV batteries and industrial rechargeable batteries (Article 7 of the draft regulations).

- Declarations of the carbon footprint, including manufacturer and factory information, total carbon dioxide (CO_2) emissions at each stage of the battery's life cycle, and independent third-party verification authority certificates (From July 1, 2024).
- Display of performance categories to facilitate identification of large and small CO_2 emissions throughout th lifecycle (From January 1, 2026).
- Implement cap values for carbon footprint throughout lifecycle (From July 1, 2027).

■For EV batteries, industrial batteries, and automotive storage batteries containing cobalt, lead, lithium, and nickel, the following points will be made mandatory (Article 8 of the same Act).

- Disclosure of the amount of recycled materials used (From January 1, 2027).
- Introduction of a minimum percentage for each type of recycled raw material (From January 1, 2030)

Materials of EU Commission

(2)Reuse Functions Required for Circular Economy of EV Batteries

The most important function in building a circular economy is to maximize the value of available assets. Maximizing the value of an effective asset means appropriately evaluating and distributing the residual value of a product as an asset and making the most effective use of it.

When an industrial product is produced, the manufacturer is responsible for ensuring the quality of the product. On the other hand, it is difficult to objectively define the value of a product that has been used for a certain period of time. Traditionally, the value of the second-hand market has been determined by the user's evaluation. In other words, the current market is an economic system in which the value of a product at the time of production is socially most easily distributed.

On the other hand, in the IoT era, the historical information and performance information of a product can represent the value of the product, and it becomes possible to secure the value and reliability not only when it is sold as an industrial product, but also when it is sold as a used product.

In this way, if the use value of a product is traded instead of the manufacturing value, the value of the carefully used product will increase or the scarcity value will be demonstrated. This will promote the effective use of non-material assets (intangible assets) as well as conventional goods. Data automatically collected by the IoT will form a new foundation of value for society. This transformation of society will change the world's material-oriented society.

In order to respond positively to such changes in the market, it is necessary to construct functions necessary for the reuse market. In other words, it will create an IoT mechanism that replaces the value of industrial products and materials with the value of data. Ensure data authenticity and define value. Data such as how much impact was applied, how many times the temperature rose above the upper limit, and, consequently, how bad the battery is, determine the value of the battery. Since the internal state of a battery cannot be grasped when it is used, reliability and performance must be evaluated by estimating the internal state. However, by collecting a large amount of such indirect data, the probability of the quality of the battery is ensured and reliability can be obtained.

(3)Reuse and Recycly Functions Required for Circular Economy of EV Batteries

Another function is to maximize the value of scarce resources. There is a high possibility that the price of rare resources will rise with the development of EVs in the future. If this is the case, the recycling of resources may proceed naturally. However, this is an optimistic scenario depending on the external environment. In general, discarded resources cannot be easily separated and recycled. This is because resources cannot be efficiently recycled without knowing where, what kinds of rare resources are contained, and to what extent. In the past, however, there was no mechanism to manage such information, so it was difficult to recycle only based on economic principles. For this reason, recycling has caused social problems through global distribution.

This externally dependent economic system may eliminate waste, but recycling will not progress. How can we promote recycling? One policy is to establish a system to ensure recycling costs at the time of manufacture and sale. In Japan, the Automobile Recycling Law was enacted in 2002 to establish a system in which users bear the costs of recycling. As a result, illegal dumping in Japan has been greatly reduced, and recycling of iron, copper and rare metals contained in catalysts has been promoted.

But it's a pre-IoT system. In the past, the cost of each distribution and processing process was high and the added value was low, which made it impossible to manage goods sufficiently. In the IoT era, traceability of goods has become possible at low cost, and it has become possible to improve the efficiency and value of distribution and processing processes according to resource information. If information on materials and appropriate separation methods can be obtained at recycling sites, the business potential of recycling will improve. In the IoT era, the value of materials can be realized by linking data such as product information.

In recent years, as the value of CO2 emission reduction through resource recycling has been added, further economic improvement of recycling has been expected.

4. Characteristics of Circular Economy of EV Batteries

(1)EV batteries, Representative of Construction of Circular Economy

Expectations for the construction of circular economy for batteries are high. This is because common products often have the same primary and secondary uses, and their secondary use value is often greatly reduced.

However, there are many differences between primary and secondary use of EV batteries. This is because EVs are vehicles that have a need for long-distance travel, and if the distance that can be traveled on a single charge decreases, the product will not meet specifications. Generally, in the case of EV, when the remaining capacity of the battery becomes 70 ~ 80%, it is said to be replacement time. In other words, in the case of self-moving product equipped with battery, such as automobile, decrease in the ratio of the driving energy to the weight of the vehicle, that is, decrease in the energy density becomes a problem directly related to the performance. As the result, even though the residual value remains at 70 ~ 80%, it is required to be exchanged. In this way, EV batteries end their primary use while maintaining high residual value. You can't use it for the same purpose, but you can use it for a long time if you use it for other purposes, especially when it doesn't move.

The representative of the secondary utilization application is the fluctuation absorption of the renewable energy. In Japan, zero-energy houses (ZEH) and zero-energy buildings are widespread. ZEH is a type of housing in which renewable energy, such as solar power generation, can be installed to reduce net energy consumption to zero. In this case, electric water heaters such as EcoCute and storage batteries are used to adjust the imbalance between fluctuating energy such as sunlight and demand. The EcoCute system converts excess solar power into heat source for hot water supply, and stores the remaining power in storage batteries for nighttime use. Consumers tend to invest in long-term facilities for housing that will last for several 10 years. This has created a huge demand for storage batteries.

Mega solar and green hydrogen production equipment will also require large amounts of storage batteries. In order for mega solar power plants to be connected to the grid, they need to supply and demand electricity to prevent sudden voltage fluctuations caused by moving clouds from adversely affecting the grid. Green hydrogen production using photovoltaic power generation will be expanded in the future, and storage batteries are needed to reduce the influence of load fluctuation on hydrogen production equipment and to reduce the maintenance cost of hydrogen production equipment. In addition, there is a growing need for emergency power generation in preparation for future urban disasters.

Batteries will play an important role in expanding applications of renewable energy. In response to these growing needs, there is no alternative but to effectively utilize the power supply capacity equivalent to that of 60 nuclear power plants, which was mentioned in Section 1. These markets are expected to expand the renewable energy market at low cost by actively applying reusable batteries instead of introducing new batteries.

In this way, the demand for storage batteries is high in the market that will expand in both primary and secondary use, and it can be said that they are the best in the circular economy. In the future, EV batteries will be expected to be effectively used for different primary and secondary applications as a leader in the circular economy, and development of batteries suitable for every application will be expected.

(2)Ecosystem Promoting Battery Reuse

In the construction of the circular economy of EV battery, there are features which are greatly different from other electric appliances. This means that it is very dangerous to leave the battery while it is charged, and that it must always be sold, used, and transported under proper control.

This means that the battery and its management system must be used in combination at all times, not as a single object. In other words, batteries are IoT type products, and they do not exert their value by themselves, but as IoT systems. At the same time, this means that those who buy and sell batteries must take into account the connection of data and management systems, and it also suggests the necessity of sharing systems within the ecosystem. When the battery is dismantled, removed from car and transported, even a reusing company that receives and uses the battery must be able to understand the condition of the battery.

The battery cannot be completely decline to zero due to its structure. It will significantly reduce the performance of the battery. In other words, the work such as transportation and disassembly is carried out in a state of being charged to a certain degree. Depending on how much the battery is charged, what kind of temperature environment it was in during transportation, what kind of vibration it was exposed to, and so on, it affects the next task. There is a need for a dynamic IoT information coordination system that manages these kinds of creatures and ensures that the history information is passed on to the next operator. This is more than just tracing the owner of the battery. This means that the IoT ecosystem in which battery users build networks is essential for the battery recycling market.

On the other hand, there is a risk that this will close the market and create a small market in which new renewable energy providers will have difficulty participating. Thus, while the ecosystem itself is not closed, but open and free to enter and leave, it is necessary to build a platform for IoT ecosystem that enables reliable management coordination while participating in the ecosystem.

(3)Challenges in Building Circular Economy

On the other hand, if we look at the current market, the market is open, but many of them are battery manufacturers and automakers. This situation cannot be helped because the circular market has just begun, but this market, which is expected to reach 10 trillion yen in 2030, cannot operate efficiently in closed loop. An open and efficient distribution market is essential for more renewable energy providers and city managers to make effective use.

In such market, the IoT dynamic information distribution platform described in the previous section is required. The absence of such a mechanism has led to a fearful expansion of the market. In building such a system, it is important to (1) secure investments and (2) realize highly reliable operations by relevant parties.

First, the platform system involves a wide range of businesses from dismantling and distribution to reuse and recycling. Moreover, the market is still immature at this point, and only a few companies can invest in large-scale platform systems. On the other hand, it is also difficult for automakers and battery makers to implement the system. In the first place, platform operators are required to have the ability to operate the IoT market by integrating new material assets and intangible assets through integration of goods and information. Because the manufacturing industry has strengths in businesses that seek to improve the quality of goods and reduce costs, there are no human resources who can contribute to improving the value of intangible assets. In order to build a platform system for the whole China and each region, it is necessary to wait for the emergence of new service providers in cooperation with local governments.

Second, market participants can realize highly reliable operations, but the market is still immature and only a limited number of companies can conduct highly reliable operations. In order to expand and grow the market safely and efficiently in such a market, it is necessary to increase the number of business operators carrying out reliable operations and promote growth. A good way to do this is to use these platforms to communicate and visualize work quality. As information on the acceptance of batteries, disposal of batteries, and utilization of battery management systems for safety must be provided to the platform, if work quality is poor, data willl show the results to the next operator. In other words, a business operator whose work quality is low cannot make a deal. In this way, companies that do not improve quality are eliminated from the market.

In addition, it is necessary to establish a system that can detect and solve problems at early stage by checking the quality of batteries at key points of distribution. To measure the quality by SOH or something like of a battery, various techniques exist at present. Conventionally, only technique requiring 10 hours or more to measure 1 battery such as charge/discharge method has been developed, but recently technique capable of performing highly accurate diagnosis in short time has also been developed. If such technologies are used effectively, the reliability of data distribution will be greatly improved. In addition to the charge-discharge method, there are various diagnostic techniques in Japan, such as the characteristic utilization method during discharge, the analysis method using the charge-discharge curve, the AC impedance method, the statistical method, the micro-SOH method, and the CC-CV discharge method. Diagnostic techniques can be broadly divided into methods for analyzing charge/discharge characteristics and methods for measuring internal resistance. In order to utilize the charging/discharging characteristics, there are various methods such as a method of analyzing partial charging characteristics, a method of making a model of a battery by repeating charging/discharging in various patterns, and the like, instead of the conventional method of charging/discharging for 10 hours or more.

In order to confirm the quality of batteries quickly and easily, it is necessary to use diagnostic techniques that match the characteristics of each type of battery.

Therefore, it is necessary to select and utilize such techniques appropriately.

5. Proposal For Creation of Circular Economy for EV Batteries

In this paper, we have shown the scale and potential of the EV battery market, which is expected to increase in the future, and the problems and the direction of the solution in forming the circular economy of the EV battery. It is pointed out that the construction of circular economy can only be realized by integrating the traditional market and industrial structure of material assets into IoT model and intangible assets, and that a dynamic information sharing platform that improves reliability is required. Therefore, we propose the following measures to establish such a system.

(1)Forming an Open Market That Does Not Closed between EV Manufacturers

First is the open market. EV batteries are expected to form a great value market for society due to the size of their residual value, the volume of supply due to the expansion of the EV market, and the rapid expansion of the market for renewable energy. These new markets greatly expand the existing used goods market and form new circular economy market. This market is large enough compared to the size of average automobile company which each automobile company takes responsibility for its disposal, it is a market that returns a large value to society that cannot be contained in a closed market.

Therefore, we propose the formation of an open market from a closed market in which automobile manufacturers and battery manufacturers engage in face-to-face transactions. We will build a data linkage platform that will enable companies such as automobile manufacturers, which are responsible for battery management, to entrust the disposal of batteries with peace of mind, and to ensure the recycling of resources toward a recycling-oriented society in the future. The platform is a data linkage system that ensures the reliability and certainty of confidential data with the involvement of local governments, and ensures the transfer of related data and battery control status to operators. Various players are expected to enter these markets in the future. It is necessary for new businesses to be able to dispose of such waste reliably.

(2)Promotion of Quality Control Methods in Cooperation With Japan

The second is cooperation with Japan in quality control and reuse/recycling methods. Japan has been developing various diagnostic technologies to control the quality of batteries. In order to utilize these diagnostic technologies and their data, it is effective to cooperate with Japanese companies that have such technologies.

There are several types of batteries, such as lithium-iron phosphate batteries and ternary batteries, and each company has its own manufacturing method and the size of the battery, so that a single diagnostic technique cannot be applied. Therefore, it is necessary to effectively utilize multiple diagnostic techniques according to the type of battery. In Japan, many diagnostic technology companies, led by the Japan Research Institute (JRI), are working together to develop utilization technologies.

In Japan, a system for detailed reuse and recycling has already been established. One such initiative is a network that uses recycled automobile parts. Although large batteries for EVs have not yet been distributed, nearly 100 companies in the fields of dismantling, reuse, recycling, and distribution cooperate to distribute and sell high-quality used automobile parts. In order to ensure the environmental friendliness of disassembly, parts are carefully removed, and if a product is damaged or faded, information is shared by taking pictures so that the point can be clearly identified. Used parts are different from new parts in that various types of deterioration have occurred. However, if it is not clear where and what kind of deterioration has occurred, recycled parts that occur over a wide area cannot be purchased through a web service. For this reason, the company ensures trust by disclosing as much deterioration information as possible that would be disadvantageous to product sales. In terms of securing trust, since improper disposal by the company selling the product will reduce trust not only in that company but also in the entire network, the company actively responds to the improvement of work quality and the sharing of ideas.

In China, it is expected that diagnostic technologies will be actively used to clarify the quality of such batteries, and a system will be established to promote the use of used batteries by clarifying the quality. However, in the distribution of used parts, it is necessary not only to distribute information, but also to improve the reliability of the companies that produce and distribute the information, and to form a market for recycling EV batteries that increases on the base of trust. IoT information management is essential for diagnosis technologies and methods to improve the reliability of such companies. It is hoped that Japan, which has a good track record in this regard, will work together to foster healthy markets.

(3)Institutional Design for Market Formation

The third is institutional design to create a healthy new market. The circular economy not only forms a market through reuse and recycling, but also serves as social infrastructure that contributes to safety, environmental value, resource conservation, and low carbon society as whole. In this sense, market formation should be promoted with appropriate government support.

Batteries in particular are dangerous goods, and if we rely only on market power, there is a concern that the number of companies that reduce costs in transportation and storage and do not manage them properly will continue to increase. In particular, in view of the future expansion of the EV market, it is necessary to actively foster and expand business operators capable of appropriate disposal. In this case, if management equipment and systems are introduced at early stage, the market will become more efficient, and new market entrants will increase in proportion to the residual value of the battery, and it is expected to develop into a large-scale market. However, it is heavy burden for companies to invest in the development of information management systems in the early stage of the market. Taking these points into consideration, it is expected that the following measures will be implemented as institutional design by the government.

④ Strict penalties for illegal dumping, which causes environmental pollution, etc. and distribution management through the construction of a system to ensure its traceability. Illegal dumping, which lies behind illegal dumping, will not disappear unless the government can crack down on the illegal outflow of waste overseas and the distribution of waste on the domestic market at an unreasonably low price. This system already exists as a system, but it is expected to further improve the quality of EV batteries as a system utilizing the information cooperation system in the region.

⑤ As in Japan, there is a method in which the purchaser of automobile purchases the automobile with the automobile recycling fee added, government manages the fee and when the automobile is dismantled and recycled, the fee is paid to each company as the recycling fee. This is based on traceability. If this can be achieved, the outflow of inappropriate waste can be avoided.

⑥ Subsidies, such as system installation costs, are provided to enterprises that conduct high-quality management at the beginning of the market. In addition, business licenses are granted to enterprises that have introduced IoT information management systems that enable a certain level of quality control, such as proper management of transportation, and the promotion of crackdowns on enterprises that fail to meet standards. The introduction of such a system can contribute to the development of circular markets by ensuring that the number of new entrants increases and that high-quality management can be implemented with policy funds. Such government financial assistance is required at the early stage of market formation, and if a certain number of business operators are fostered, it will be possible to operate business independently without government support in order to improve efficiency and improve business efficiency through market expansion.

Currently, several large companies have grown up and the market is in early days. However, only a few companies have introduced systems for high-quality battery management using highly reliable technologies. In this early stage of the market, new measures are needed to make it a market.

(4)Formation of New Industrial Structure Based on Recycling

Finally, we show the new mechanism created by the recycling market of EV batteries and its effectiveness. As we have seen, the battery circular economy is the starting point for formation of market that combines the intangible economy such as brand value and intellectual property rights with the material economy.

In the circular economy, the quality cannot be equalized as in the conventional monolithic product. This is because it is necessary to distribute products that are the same but have different values. Therefore, information such as the history record, characteristic analysis, and the present state of the product is combined and distributed, and the value is generated in the product meeting the needs of the user. In other words, in the circular economy, not only the value of the primary use, but also the market of the secondary use in which things and information connected to the value of various intangible assets are fused is formed.

Traditionally, products have been produced primarily for their primary use. Secondary use was only additive and a small market outside the industrial structure. However, in the case of products such as EV batteries where the value of secondary use accounts for a large part of the product value, the value of the recycling market will increase, and the product value will not be determined only by the value of primary use. For example, in the case where the battery is reused for adjusting the fluctuation of wind power generation, the battery haing high followability to the fluctuation and uniformity of charging and discharging characteristics is highly evaluated in the secondary use stage. Such batteries have high value for secondary use and are traded at high prices, resulting in phenomenon in which the value of the secondary use of the battery is included in the evaluation of the automobile when the product is manufactured. In other words, batteries will be a product of the combined market of primary use market as automobiles and secondary use market such as renewable energy. In addition, the secondary market is a market in which intangible assets, which combine goods and information and are difficult to handle in the past, are added. In this way, the automobile and renewable energy markets will create a new modular industrial structure in which IoT links multiple markets centered on core components such as batteries.

Historically, after the industrial pyramid structure developed in Detroit in the United States, which centered on conventional automobiles and other final industrial products, the industrial structure of modular ecosystem of single industry flourished, centered on Shenzhen, in the fields of home electronics, smartphones, robots, and so on. This new change in industrial structure will create a multi-industry IoT modular ecosystem centered on components that incorporate the value of intangible assets.

In China, IoT product industries such as the robot industry and smartphones have been successfully established. It is hoped that these findings will be used to the fullest extent to promote the formation of a new industrial structure for the circular economy.