SIEMENS

全球气候治理下中国商品及企业绿色出海之路

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摘要

气候变化是 21 世纪人类和地球面临的最大环境威胁，为应对全球气候变化，实现可持续发展，2015 年《联合国气候变化框架公约》缔约方通过《巴黎协定》设定了"将全球平均气温较前工业化时期上升幅度控制在 2℃ 以内，并努力将温度上升幅度限制在 1.5℃ 以内"的目标。2023 年，联合国政府间气候变化专门委员会（IPCC）发布了第六次评估报告的综合报告《气候变化 2023》（AR6 Synthesis Report: Climate Change 2023），报告数据显示[1]，工业化以来，全球气温已上升 1.1℃，这使得世界各区域正面临着如海平面上升、极端天气时间频发、生物多样性减少、水资源短缺、病媒传播疾病的加速蔓延等一系列前所未有的挑战。

为应对气候变化这一共同问题，欧洲等发达市场加快围绕碳市场和碳关税、产品全生命周期可持续性、价值链管理与披露等方面做出响应行动。以应对气候变化的领跑者欧盟为例，欧盟委员会于 2019 年发布了《欧洲绿色新政（European Green Deal）》，就应对气候变化提出了"fit for 55"一揽子计划提案。其中，包含碳边境调节机制（Carbon Border Adjustment Mechanism，下文简称 CBAM），规定基于欧盟碳排放价格对进口商品内含的

碳排放征收关税。在产品全生命周期可持续方面，欧盟于2020年发布了新的循环经济计划（Circular Economy Action Plan，下文简称CEAP），加快改变线性经济发展方式，增加可循环材料使用率，引领全球循环经济发展；2023年，欧洲议会通过了《欧盟新电池法规》，聚焦电池行业，在原电池指令的基础上对电池生产与进口的可持续性与安全性提出更高要求。在强制性价值链管理与披露方面，全球范围内，可持续发展信息的披露正逐渐从自愿性向强制性转变，欧盟于2022年分别推出了欧盟企业可持续发展报告指令（Corporate Sustainability Reporting Directive，下文简称CSRD）和欧盟可持续发展尽职调查指令（Corporate Sustainability Due Diligence Directive，下文简称CSDDD），覆盖了对供应链上企业的管控与强制性信息披露，影响范围扩展到在欧盟符合监管条件的第三国企业。

在此背景下，全球的合规监管政策都要求企业积极进行绿色低碳转型，这为中国出海企业带来了全新的挑战与发展机遇；而数字化与低碳化的"双轮驱动"是企业实现绿色转型的破局之道，以端到端的数据底座为基础，驱动全价值链的绿色转型，赋能中国企业绿色出海。首先，出海企业应制定合理的碳管理战略并积极运用数字技术摸清"碳家底"，构建夯实的端到端的碳数据底座；其次，出海企业应从全价值链出发驱动绿色转型，从产品设计、生产制造、电气化以及楼宇方面探索并引进符合自身转型需求的领先技术，如在产品设计阶段应用虚拟仿真及3D打印技术，提高材料利用率，减少浪费；在产线部署能源管理工具与解决方案，有效管理并提升生产制造阶段的能源效率；在配电网络部署一站式智能配电管理解决方案，支持出海企业对其的智能运维与低碳管理；在楼宇中应用传感器和物联网（IoT）等技术推动智慧楼宇建设，实现节能减排的同时，提高运行效率、安全度与舒适度。

政策方面，中国政府已为出海企业营造了开放的政策环境，为加速出海企业在绿色低碳转型的同时顺利开展目标市场业务，可从以下方面出发：

1. **完善监管评估和市场交易机制，加强标准体系建设**：当前在推动企业绿色转型方面已出台一系列政策，政府可牵头联手行业组织共同完善数据与应用相关的标准、认证、碳排放核算、市场交易等规范化和标准体系；

2. **促进国内多元主体合作，深化国际合作与交流**：对内推动与高校、科研机构、企业等主体间的共创与合作，对外深化与国际组织的合作与交流，积极参与国际气候治理，为出海企业提供发展与支持平台；

3. **加强财政、金融和人才支持，建立示范推广机制**：为企业绿色转型提供财政支持，包括但不限于适度补贴、退税、鼓励金融机构提供绿色转型项目低息贷款；同时，为企业提供专业人才培训支持，由此降低企业转型成本与风险。

1. 全球气候治理分析及中国企业全球化布局全新监管要求

当前，国际社会与各国政府普遍加强了气候治理与环境保护的合作努力。中国出海企业需要不断提高各层次的碳管理能力，才能更好应对不同的合规监管要求与多变的政策格局。

1.1. 欧盟率先征收碳关税带动国际经贸规则变化

欧盟作为中国企业重要的出海目的地，已在绿色新政下提出"Fit for 55"一揽子计划作为实现目标的具体路径。其中，对中国企业影响最大的当属欧盟碳边界调节机制（EU CBAM）。EU CBAM 计划对进口到欧盟的商品以配额的方式征收 "碳关税" ，防止碳泄露的产生，避免损害自身气候政策的完整性及有效性。

政策概览	
欧盟碳边境调节机制（EU CBAM）	
立法进程	欧盟理事会于 2023 年 4 月投票通过 CBAM，目前已完成整个立法程序
预计生效时间	过渡期：2023 年 10 月1 日—— 2025 年 12 月 31 日 正式期：自 2026 年 1 月 1 日起
覆盖范围	钢铁、水泥、铝、化肥、电力、氢气行业
对中国出海企业的影响	由发达国家主导的"基于规则"的以"碳市场和碳关税"为核心的新全球气候治理秩序在逐步形成，以 CBAM 为首的"碳关税"对中国出口贸易造成直接影响，尤其是碳密集型出口行业；其中将对中国出口占比较大的钢铁、铝业等带来巨大挑战

图 1 欧盟碳边境调节机制（EU CBAM）政策概览

EU CBAM 的落地实施将对国际贸易格局产生重要影响，作为一项调节国际贸易的边境机制，其他国家很可能紧跟欧盟步伐，建立类似"碳关税"机制。

1.2. 产品全生命周期的可持续要求增强

随着国际社会逐步从线性经济向循环经济转型，欧盟等国家和地区陆续出台了与循环经济体系相关的政策制度以及与产品碳足迹相关的强制披露要求。

2020 年 3 月 11 日，欧盟委员会发布了新的循环经济行动计划（CEAP），首次提出了一个全面的产品政策框架，将循环经济理念贯穿产品设计、生产、消费、维修、回收处理、二次能源资源利用的全生命周期，对产品进行可持续的管理。

图 2 欧盟循环经济行动计划优先考虑的 7 个关键产品价值链

2023 年 6 月欧洲议会通过了《欧盟新电池法规》，要求所有进入欧盟市场的电池以及欧盟本土生产的电池都必须遵守，对于容量超过 2kWh 的电动汽车（EV）电池、轻型交通工具（LMT）电池和可充电的工业电池，企业将必须提供碳足迹（PCF）声明和标签。

图 3 欧盟新电池法规政策概览

2022 年 3 月，欧盟委员会通过可持续产品生态设计法规（ESPR）提案。将生态设计指令的范围扩展到除了食品、饲料和药品外的所有产品。

图 4 欧盟可持续产品生态设计法规（ESPR）

在以循环经济为导向的监管变化趋势下，以发达市场为目标的出海企业亟需关注产品全生命周期管理、碳足迹披露、碳足迹可追溯等方面的要求，

考虑产品在整个生命周期中的环境和社会影响，实现资源的高效利用，降低碳排放和废弃物，从而满足不同国家和地区的准入标准。

1.3. 可持续发展信息披露由自愿向强制转变

随着投资者、消费者和利益相关者对企业的可持续性表现愈发关注，可持续发展信息披露逐渐从自愿性向强制性转变。例如，欧盟企业可持续发展报告指令（CSRD）和欧盟可持续发展尽职调查指令（CSDDD）从法律层面将可持续发展信息披露尤其是碳排放相关的指标转变为强制性的合规要求，并且将信息披露的范围从企业自身扩展至供应链的上下游。

👆 **政策概览**

欧盟企业可持续发展报告指令（CSRD）	
立法进程	欧盟理事会于2022年11月正式通过 CSRD，目前已完成整个立法程序
生效时间	CSRD 于2022年12月正式生效，并要求 18 个月后由欧盟成员国具体实施
覆盖范围	• 适用于设立在欧盟境内的大型公司，满足以下条件中任意两项： （1）拥有超过 250 名员工； （2）净营业额超过 4000 万欧元； （3）总资产超过 2000 万欧元。 • 适用于在欧盟监管市场上市的公司，包括中小型公司（微型公司除外） • **在欧盟营业额超过 1.5 亿欧元，且在欧盟至少有一家子公司或分支机构的非欧盟公司**
对中国出海企业的影响	CSRD 拥有更细化的披露要求与更广泛的披露信息范围，将显著增加范围内出口企业的监管成本等；同时，由于 CSRD 要求企业披露价值链信息，对于相关供应链上下游企业，也需要配合履行合规义务，依规披露 ESG 信息。此外，CSRD 引入的独立鉴证机制也对企业可持续信息披露质量提出更严格的要求

图 5 欧盟企业可持续发展报告指令（CSRD）

欧盟可持续发展尽职调查指令（CSDDD）	
立法进程	欧盟委员会于2022年2月公布了 CSDDD 提案，欧洲议会于2023年6月表决通过拟议的 CSDDD
生效时间	CSDDD 于2023年通过，2024年成为欧盟的法律，成员国应在2026年前将其转化为自己国家的法律并实施
覆盖范围	CSDDD 将适用于欧盟和非欧盟企业，包括： • 对于欧盟企业，（1）员工超过250人，且全球年净营业额超过4千万欧元；（2）自身未达到上条标准，但该企业员工超过500人且是全球年净营业额超过1.5亿欧元企业集团（group）的最终母公司 • 对于非欧盟企业，（1）全球年净营业额超过1.5亿欧元，其中至少有4000万欧元产生于欧盟境内；（2）自身未达到上条标准，但该企业是员工超过500人的企业集团（group）的最终母公司，且该集团全球净营业额超过1.5亿欧元，其中至少有4000万欧元净营业额产生于欧盟境内
对中国出海企业的影响	可持续尽职调查合规将成为中国企业进入欧盟市场必须跨过的"门槛"，范围内企业以及相关供应链上下游企业需要按规进行供应链尽职调查，采取预防措施和补救措施等，及早发现和预防企业商业行为中潜在的人权和环境风险，实现可持续的供应链合规

图 6 欧盟可持续发展尽职调查指令（CSDDD）

中国企业的出海企业愈发需要将供应链碳管理作为公司战略发展规划中的重要部分，不断提升供应链碳管理水平，在严格的碳管理监管合规要求环境下保持强有力的综合竞争力。

2. 全新气候治理要求下中国企业面临的挑战分析

当前，为满足全球合规政策要求，在中国"双碳"目标指引下，绿色转型逐渐成为中国企业出海的必选项。而在此过程中面临的挑战主要在战略与管理、数据与应用两大方面。

2.1. 战略与管理

- **平衡"发展"与"减碳"之间的矛盾**：受全球经济震荡、地缘冲突等因素影响，出海企业的业务增长面临较大挑战，而绿色转型离不开专业人才、资金以及技术的投入，包括对政策趋势的追踪与分析、环保设备购买、绿色产品研发等。因此，如何在保持自身业务增长同时实现绿色转型，是企业面临的重大的挑战；

- **碳风险识别与把控能力不足**：随着全球应对气候变化政策和行动的深入，出海企业在政策制度、产品标准、供应链要求等方面需要应对不确定性风险。受这些动态因素的影响，在碳风险管理领域存在以下两方面的挑战。一是由于企业管理层缺乏可持续发展相关的知识和经验、对气候政策的理解存在偏差等，导致未能及时识别与规避碳风险。二是企业管理层对长期性、系统性的碳风险识别程度不够，导致未能准确认知和把控碳风险。

- **碳治理结构不健全**：碳管理的意识和职责应渗透到企业治理结构的各个层级，从而激励内部各利益相关集团达成一致的碳减排目标。在组织架构和流程方面，很多企业尚未建立和落实特定的碳管理的部门或团队，即使在部分已成立相关部门或团队的企业里，也存在由其他部门人员兼任的情况。这将对企业加强碳排放监测与报告，满足合规要求，制定风险应对策略等带来人力和资源上的挑战；

- **企业内部协同机制不完善**：将碳管理融入企业经营管理的各个环节是实现可持续发展和应对碳风险的重要策略之一。在碳排放核算中，相关活动数据涉及企业经营管理的各个环节，这些数据通常由不同部门进行统计和管理，倘若缺乏行之有效的协作与管理机制，则无法形成统一的汇总口径，较难进行碳数据的规整与统计，也很难保证碳数据的质量与完整性；

- **价值链上下游协同能力有限**：全球气候政策的监管趋势逐渐从企业自身碳排放扩围至供应链上下游碳排放。越来越多的企业因为法规与监管政策要求，开始向供应商索要碳足迹数据，设定供应商碳足迹指标来降低价值链合规风险。此外，目前多数企业仅关注范围一和范围二排放，较少考虑全价值链的碳中和，尽管一些企业向供应商提出了100%采用绿电、将原材料的碳足迹纳入评价指标等要求，但供应链减碳往往需要通过链主企业带动，以及供应链企业在提升自身的数字化水平或者碳足迹计算方面的努力，整体需要较大投入，也导致供应链减碳目前难以真正落到实处。

2.2. 数据与应用

- **数据透明度不足：**
  - **碳排放计算标准不一致**：较多出海企业的供应链跨越多个国家与地区，涉及多个环节和参与者。然而，由于数据收集和共享的碳排放核算相关技术、标准、流程和文化的差异性，供应链中的数据存在透明度低、缺乏可比性的通病。出海企业无法从供应商处获得准确全面的碳排放计算相关信息与数据，导致其难以全面了解原始数据的收集范围、涵盖系统边界、数据来源等信息，进而无法整合上下游碳排放数据；
  - **对于数据安全的担忧**：部分企业不愿意在数据安全保护缺失的情况下透露自身的碳数据，尤其是涉及到敏感业务信息时。这使得出海企业在获取价值链数据时受限，进而影响其对产品碳足迹的准确核算；

- o **数据报告不完整**：部分出海企业尚未建立完善的报告机制或激励措施促使供应商披露其碳排放数据，价值链碳管理数据透明度不足，进而导致碳管理数据的不完整或缺失，限制产品碳足迹核算的准确性。

- **数据追溯性有限**：在复杂的供应链中，产品的原材料、生产过程和分销渠道往往涉及多个参与者，这些参与者可能位于不同的国家或地区。然而，由于数据来源缺乏记录，产品的碳足迹往往很难追溯到具体的参与者和环节；同时，当出海企业依赖多层次供应商时，他们可能难以追溯产品中所使用的材料和零部件的来源。这种追溯困难使得价值链每个阶段碳足迹计算变得十分困难。

- **支撑全面绿色转型的技术路径尚未明晰**：绿色转型需要企业具备相应的技术和能力，部分企业技术力量薄弱，开展碳排查碳核查、推动节能降耗工作难度大。

  - o 从产品设计角度，产品的 80%的环境影响因素都是在其设计阶段决定的。需要从全生命周期出发平衡经济性、功能性、可靠性、可持续性等指标，而其关键性能数据都需要完成设计与模拟，这对技术应用要求较高，目前多数企业在这方面有提升空间；

  - o 从生产制造角度，钢铁、化工等传统高能耗、高污染行业以及电池、电子、新能源等出海业务领先的行业，一定程度上都存在能源结构高碳化、工艺流程复杂的情况，虽然目前很多企业在数据采集和生产管理等方面有了一定水平的技术应用，但产线、流程及能源管理效率与质量仍有待提升；

- 从电气化角度，缺乏对大量分散安装的电气设备的管理手段，难以进行远程运维以及实时了解配电网络中的设备运行状况，影响对设备管理效率；

- 从楼宇角度，建筑物内部设施和系统的智能化控制与管理，以及楼宇的运行效率、安全度、舒适度、节能环保水平仍有较大提升空间；

- 从供应链角度，基于对数据安全的担忧、上下游核算标准不一致等原因，导致价值链上的碳数据不透明，供应链上下游企业的碳排放计算和监控缺乏精准的数据支撑。

3. 通过数字化与低碳化"双轮驱动"，赋能中国企业绿色出海

为应对上述挑战，出海企业应根据自身发展情况制定可持续发展战略，并将其与自身业务发展战略紧密融合，结合自身禀赋，积极应对挑战，识别并把握发展机遇，以平衡"发展"与"减碳"之间的矛盾，构建组织内部治理体系，确保从顶层设计到底层实施贯彻落实可持续发展战略。其关键在于以数字化与低碳化的"双轮驱动"破局，以端到端的数据底座为基础，驱动全价值链的绿色转型，赋能中国企业绿色出海。

3.1. 端到端的数据底座

企业合理制定自身的碳达峰、碳中和发展战略，须以精准盘查碳排放基线为起点，构建碳减排的数据底座。以汽车行业为例，数字化解决方案能够为企业提供可靠的产品及组织碳排放数据，识别碳排热点，从而释放减碳潜力。

在汽车行业，由于碳足迹核算流程长、数据量大、运算复杂等难点，面对逐步形成的碳贸易壁垒，相关出海企业仍在如何精准、自动计算企业产品

碳足迹上面临着困难和挑战。通过应用数字化技术，能够有效解决企业科学构建减碳战略路径及策略困难、缺乏产品级碳排放数据基础等痛点，例如某汽车企业的车侧围产品制造工厂通过与西门子公司合作，部署了产品碳足迹数字化解决方案，逐步推广全厂产品碳足迹可信精算与追溯：

- **精准高效自动化量化生产制造过程碳排放**：依托边缘计算技术，从 Energy Manger Pro、MES 等工厂 IT 及 OT 系统自动采集产品相关碳排放数据并通过建模精准分解。

- **贯穿供应链的产品相关碳排放数据可信安全交换共享**：在无需披露供应链敏感信息前提下，可实现供应商原材料的碳排放信息的安全安全可信交换共享。

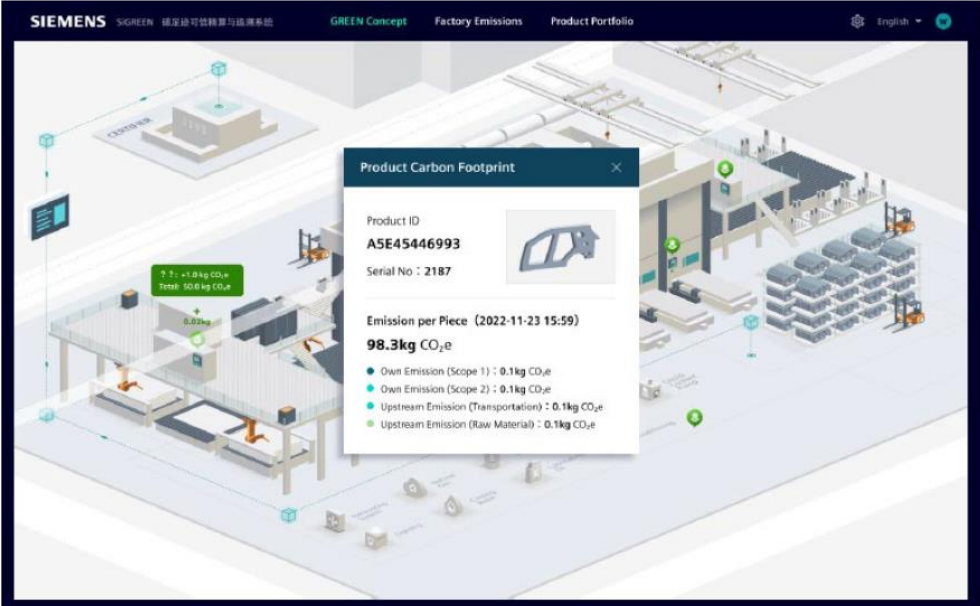- **车侧围产品碳孪生**：可视化呈现产品碳足迹旅程；多维度数据分析及可视化呈现，辅助产品碳排趋势变化监测，并为减碳路径规划及减碳策略指定提供数据支撑。

图 7 汽车企业产品碳足迹数字化方案应用案例

3.2. 全价值链的绿色转型

3.2.1. 绿色产品设计

产品研发是整个产品生命周期的起始，绿色产品设计是企业绿色转型的源头，对企业减碳具有重要意义。

为助力企业进行绿色产品设计，产品研发设计的软件平台需要提供面向产品的"可持续性发展"设计模块，帮助用户完成产品设计的同时，针对每个零件的碳排放数据及生产该产品所需的水消耗数据进行计算和统计。基于当前设计，工程师也因此能在设计阶段看到整个产品的碳排放、碳积分数据。

绿色设计同样离不开提高材料利用率，减少材料消耗。企业需在设计阶段进行优化，可采用创成式设计工具以及基于此的3D打印解决方案，减少原材料浪费、提高生产效率，减少零部件库存和企业资金压力。其次，还需充分使用现有零部件而不是重新设计新零件。使用现有成熟的产品零件、减少浪费，避免新设计的零件在产品验证、重新进行模具设计、重新采购等各方面造成的资源和成本浪费，这也是减碳和绿色产品设计的要素之一。最后，通过数字孪生技术在数字世界进行仿真、模拟和验证，确保在真实世界达到可持续性指标的同时，实现产品可靠性、功能性、经济性指标的平衡发展。

市场上先进的解决方案和成功的案例如工业软件NX和使用NX平台的Geolus解决方案，在新能源汽车、风电设备、光伏设备、太阳能设备等的产品研发和设计中，比亚迪电池、国轩高科、上海电气风能设备、海装风电、中车风电等优秀企业在产品绿色研发、仿真、数据管理、3D打印等已有成功应用经验。

3.2.2. 绿色生产制造

绿色生产制造的关键在于能源与生产数据的透明化及其效率的持续优化，在本节，我们将以能源管理、机械加工以及流程行业的可持续为例进行阐述。

3.2.2.1. 能源效率管理和持续优化

为实现制造过程的高能效，提升能源使用效率并减少环境影响，需实时进行能耗数据分析和能源管理优化。这就要求企业通过部署数字化的能源管理工具和解决方案，结合人工智能等前沿技术，可以自动实时采集能耗数据并进行工厂能耗透明度分析，监测并管理生产过程中的能耗、产量、设备运行状态等信息，识别可能的节能减排机会，预测潜在的设备故障，从而实现成本节约和环境保护的双重目标。

2023年成功获评世界经济论坛"可持续灯塔工厂"的西门子成都工厂通过全面部署数字能源产品Energy Management，使得2019年至2022年期间，在产量提升92%的基础上，单位产品能耗降低24%，单件产品废弃物降低48%，实现了经济效益与环境效益的"双赢"。

3.2.2.2. 数字化机床的节能高效

机械加工广泛使用的机床设备往往需要高额投资，机床的可用性和使用效率对加工原材料的资源效率和加工过程中的能源效率关系重大。

机床制造商和机床用户需要通过动态优化和消除加工过程中的不确定、不可控因素，全面提升机床切削性能和加工效率，实现刀具折断或损坏的提前预测或报警，在提升机床运行安全性的同时，减少刀具损耗，降低额外加工成本及机床维修成本。例如ACM Suite等自适应加工与刀具监测解决方案，提高机床生产效率可达7%，每台机床年节约生产成本可达60,000元，降低电力消耗可达15,000千瓦时，有效推动数字化机床的节能高效。

3.2.2.3. 流程行业的可持续发展

在新产品工艺研发阶段，建立数字化实验室，通过数学模型与计算机仿真的手段搭建合成反应的工艺模型，优化研发路线，减少物料损耗，加速创新与研发。

在工厂设计阶段，综合考虑整个生产系统的能耗优化、副产品的循环利用、以及废物的回收与重新利用，从绿色低碳的角度对工厂及供应链进行重新设计。利用gPROMS等工艺仿真优化软件进行工艺-工程一体化设计，从根本上对整个生产系统进行绿色低碳升级；通过生产系统工艺数字孪生平台例如gDAP等建立虚拟产线，在设计阶段验证生产策略并预计产品质量与物料消耗；采用生产系统状态感知能力的自适应模型（AI）实时在线优化生产策略（RTO），通过整个设计空间探索制定绿色低碳的生产策略。

在生产阶段，既调稳又调优地实施在线生产系统与预测性模型控制。通过提高产品质量与收率，降低单位生产能耗与物料消耗，从而降低整个生产系统的碳足迹，实时在线系统保证不断优化与精准生产控制。

3.2.3.　可持续电气化转型与智慧楼宇

3.2.3.1.　可持续电气化转型

电力能源的可靠运行是企业减少自身碳足迹的先决条件，也是城市基础设施的重要组成部分。其中，配电网络扮演着非常重要的角色，但对于出海企业的后期运维而言，也面临着缺乏高效管理大量分散安装的设备的手段、缺乏统一高效的实时能源监控平台以及合理的能效评估办法、无法实时了解配电网络设备运行状况、难以实现远程运维等诸多挑战。

针对这些挑战，企业可通过部署一站式智能配电管理解决方案，实现智能运维与低碳管理，包括：

- **状态透明**：通过数字化的手段，将底层传感器、数据采集单元、智能在线监测装置等数字化应用串联起来，实时了解设备的运行状态，进行高效资产管理，降低产品生命周期成本，优化资产投资；

- **能源监控**：通过对能源消耗状况进行评审，将产品产量与能耗情况相结合，确定核心设备的KPI，通过对标杆值和基准值的计算，引导用户不断优化能耗水平，减少碳排放；

- **高效运维**：通过监测和分析对设备故障进行实时预警，并将维护保养计划于流程设置在系统中，实现从计划性维护到预测性维护的转变，降低设备损坏的概率，使运维管理系统更加主动和高效。

例如，国内某机场航站楼通过采用数字化配电解决方案和绿色低压电气产品，应用西门子电柜管家Panel Manager，实现现场配电室级的数字化，支持机场的智能运维、低碳管理。

3.2.3.2. 智慧楼宇

出海企业应当把握数字化、智能化融合发展的契机，引入智能楼宇作为建筑节能降碳的解决方案，减少自身碳排放。在进行智能楼宇转型时，企业可参考以下解决方案：

- **设备互联和自动化**：通过传感器和物联网（IoT）技术，实现楼宇内部设备和系统的互联，实时采集设备数据；基于采集的数据，实现自动控制系统，如自动调节照明、空调、供暖等设备，从而提高能源效率

- **数字化电能监控系统**：实时采集与分析能源消耗模式和趋势，识别能源浪费点，为能源管理决策提供准确的数据支持，推动企业根据ISO50001实施能源管理

- **智能环境调节和办公布局**：员工通过智能设备自定义工作区的环境设置，提供更优质的办公环境；基于实时数据，系统分析员工分布情况，优化办公布局，确保员工的舒适度和便利度

以机电行业为例，作为中国的主要出口产品之一，在国内市场竞争日益激烈的情况下，如何跟随一带一路挖掘出海的业务机会成为众多机电类企业不得不思考的问题。"洛克美森"就是这样一个正在尝试转型的企业，其在济南建设的"零碳智慧工厂"，通过引入西门子等公司的前沿技术，采用智慧能碳管理平台ECX实现对工厂能源消耗和碳足迹的实时监测，采用智慧微网管理平台MGMS对厂区安装的光伏、储能、充电桩等新能源系统进行实时管理调度，实现工厂用能100%的绿色替代，以及采用智慧园区管理平台SC Insights X实现对工厂所有智能化系统的集成和统一管理，有效提升工厂的运营管理效率。

图 8洛克美森零碳智慧工厂

3.2.4. 绿色供应链管理

数字化技术可以通过精准的数据支持、实施监控和碳足迹核算，有效管理供应链碳排放影响因素，协调供应链上下游采取减排行动。以下为企业可以参考与应用的数字化低碳供应链管理方案：

- **数字化供应链管理系统**：使用传感器、物联网技术等，实时监测供应链环节中的能源使用和碳排放情况；

- **数字化的供应商评估与管理机制**：在供应商评估体系中引入环保评估指标，利用数字化技术，实时跟踪供应商的环境绩效，并建立数字化的风险管理机制，评估供应商的环境和社会风险；

- **数字化物流管理**：利用数字化技术优化企业的物流网络和物流能力。

对于出海企业而言，需正确识别并有效追踪自身价值链中各环节的碳排放热点与减排潜力，实现价值链协同脱碳。本节将以化工行业为例，阐述数字化解决方案如何为工业企业搭建价值链的合作纽带，助力脱碳进程。

化工行业作为高能耗和高污染的重点行业，标准一致的核算方法、透明可信的价值链数据交互、以及上下游协同碳管理对化工行业脱碳显得尤为重要。企业碳管理开发数字化解决方案，需要从价值链层面高效完成出海企业与其上下游及第三方核查机构的数据交互，在实现碳足迹透明化及价值链上下游之间的高效协作的同时，有效提升出海企业碳排放相关数据的真实性、准确性与综合认可度。携手可持续发展（TfS）是由化工行业推动的一项行业领先的倡议，其中47家成员企业已与西门子等企业合作完成数字化碳足迹解决方案的全面部署，根据交互数据及自身碳排放情况建立气候中和价值链，通过高质量整合全价值链的碳排放，最大程度的推动和加速整个化工行业实现低碳转型。

图 9 供应链碳排放数据的安全可靠共享与协同生态

4. 政策建议

通过为中国本土制造业企业，尤其是面向海外市场的出海企业提供更加丰富的产品、技术和解决方案支持，对企业绿色转型提供正向激励、减轻转型成本、降低转型风险，进而推动行业向更加环保和可持续的方向发展，促进绿色低碳转型的同时顺利开展目标市场业务。

4.1. 完善监管评估和市场交易机制，加强标准体系建设

目前在推动企业绿色转型方面已出台一系列政策，但数据与应用相关的标准、认证、碳排放核算、市场交易等规范化和标准体系仍需完善。建议由政府部门牵头进一步完善碳监管和评估机制，联合权威行业组织评估企业的绿色低碳转型进展和环境绩效，包括进一步完善排放标准和减排要求、开展环境审核和评估、完善碳市场价格形成和交易机制等措施，以推动企业履行环境责任，实现可持续发展。以行业为导向，完善绿色产品标准体系和环境认证机制，提升企业产品的国际信誉和市场竞争力。推动构建重点行业减污降碳协同增效系列标准体系以及工业行业企业的环境信息披露标准，帮助出

海企业有效提升工业领域的碳数据披露质量。引入具有国际权威性的第三方认证机构，满足企业出海时的国际绿色认证要求。

4.2. 促进国内多元主体合作，深化国际合作与交流

对内促进政府、企业、科研机构、行业协会和社会组织间的合作协调，推动多元主体的有效合作机制，例如政府牵头的联合工作组、企业和科研机构组成的行业组织、行业内交流活动和加强信息共享等方式，以促进绿色低碳转型的推进和实施。对外积极参与国际气候治理，共享绿色发展经验，加强技术和信息交流，加强低碳发展合作，推动建立相互认可的碳核算标准和体系。以新能源等出海产业为抓手先行推动中国绿色标准与国际标准对接，促进中国市场内各类所有制企业共同参与标准制定，为企业提供国际合作的机遇和平台。

4.3. 加强财政、金融和人才支持，建立示范推广机制

对企业的绿色转型提供广泛的财政支持以帮助企业减轻转型成本和风险，包括根据企业的减碳水平给予适度补贴或专项的绿色出口退税、对采取低碳化产品和技术给予补贴和奖励、鼓励金融机构提供绿色转型项目低息贷款，以减轻企业的转型成本和风险。由政府部门或行业组织牵头提供绿色转型和出海业务的人才培训和能力建设项目，帮助企业提升低碳发展水平，适应目标市场的标准、需求，包括更广泛的技术咨询、技术培训、专业认证和人才引进等。鼓励城市、园区选取本土企业出海的重点行业开展企业减碳的试点示范工作，筛选一批出海企业成功实现减碳、促进海外业务增长的成功案例予以宣传，在行业推广复制成功方案。

5. 结束语

共同应对气候变化已成为全球共识，监管环境的变化和绿色化、低碳化的必然趋势为中国出海企业带来全新的机遇与挑战。出海企业应充分运用数字化技术赋能自身绿色转型，加快适应国内外碳管理与政策体系持续完善的宏观趋势，为自身业务发展开拓更广阔的空间。

西门子将运用自身技术与经验，继续与中国结伴前行，通过数字化与低碳化"双轮驱动"，赋能中国企业绿色出海。

SIEMENS

The Green Path for Chinese Goods and Companies Going Abroad

Siemens AG
March 2024

Abstract

Climate change poses the greatest environmental threat to humanity and the planet in the 21st century. To tackle the negative impacts of climate change and achieve sustainable development, the parties to the United Nations Framework Convention on Climate Change (UNFCCC) adopted the *Paris Agreement* in 2015, setting the goal to "hold the increase in the global average temperature to well below 2 degrees Celsius above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5 degrees Celsius above pre-industrial levels". In 2023, the Intergovernmental Panel on Climate Change (IPCC) released *AR6 Synthesis Report: Climate Change 2023*, which shows that [1], since the industrial revolution, global temperatures have increased by 1.1 degrees Celsius. This has led to unprecedented challenges such as rising sea levels, frequent extreme weather events, reduced biodiversity, water scarcity, and the accelerated spread of vector-borne diseases in various regions of the world.

To address the common issue of climate change, developed markets such as Europe have accelerated their response actions around carbon markets and tariffs, product lifecycle sustainability, value chain management and disclosure. Taking the European Union (EU), a frontrunner in addressing climate change as an example, the European Commission released the European Green Deal in 2019, proposing a "Fit for 55" package of legislation to address climate change. It includes the Carbon Border Adjustment Mechanism (CBAM), which stipulates the imposition of a tariff on the carbon emissions contained in imported goods based on the EU's carbon emission price. In terms of product lifecycle sustainability, the EU released a new Circular Economy Action Plan (CEAP) in 2020, accelerating to change the linear

economic development approach, increasing the use of recyclable materials, and leading the global circular economy development. In 2023, the European Parliament adopted the new Batteries Regulation, which focuses on the battery industry and puts forward higher requirements on the sustainability and safety of battery production and import based on the original Battery Directive. In terms of global mandatory value chain management and disclosure, the disclosure of sustainability information is gradually moving from voluntary to mandatory. In 2022, the EU introduced the Corporate Sustainability Reporting Directive (CSRD) and the Corporate Sustainability Due Diligence Directive (CSDDD), which cover the control and mandatory information disclosure for companies in the supply chain and extend the scope of influence to third-country companies which meet the regulatory conditions in the EU.

In this context, global compliance and regulatory policies require enterprises to actively carry out green transformation, which brings brand-new challenges and development opportunities for China companies going abroad. And the "Dual drivers" of digitalization and decarbonization is a breakthrough way for enterprises to realize green transformation, based on the end-to-end data base, driving green transformation across the whole value chain and empowering Chinese enterprises to go aboard in a green way. Firstly, companies going abroad should formulate suitable carbon management strategies and actively adopt digital technology to find out their "carbon footprint" and build a solid end-to-end carbon data base. Secondly, they should start from the whole value chain to drive green transformation by exploring and introducing cutting-edge technologies that meet their transformation needs for product design, manufacturing, electrification, and buildings. For example, they can apply virtual simulation and 3D printing technologies in the product design stage to improve material utilization and reduce waste. Besides, they can also deploy energy management tools and solutions in the production line to effectively improve energy efficiency in the manufacturing stage and deploy all-in-one smart distribution management solutions in the power distribution network to support smart operation and maintenance, as well as low-carbon management by China companies going abroad. Moreover, it is suggested to apply technologies such as sensors and the Internet of Things (IoT) to promote the construction of smart buildings, realizing energy saving and emission reduction while improving operational efficiency, safety, and comfort.

Concerning government policies, the Chinese government has created an open policy environment for companies going abroad, accelerating the green and decarbonization transformation of enterprises while smoothly carrying out business in target markets. The following aspects can be considered:

1. **Refine regulatory, assessment and market mechanisms, enhance standard framework:** a series of policies have been introduced to promote

the green transformation of enterprises, and the government can take the lead in joining hands with industry organizations to improve standardization and standardization systems, related to data, application, standardization, carbon emission accounting, and market trading.

2. **Promote cooperation among diversified domestic stakeholders, deepen international cooperation:** internally, promote co-creation and cooperation with universities, scientific research institutions, enterprises, and other entities; externally, deepen cooperation and exchanges with international organizations, actively participate in international climate governance, and provide a development and support platform for companies going abroad.

3. **Strengthen financial, fiscal and talent support, establish demonstration and promotion mechanisms:** provide financial support for enterprises' green transformation, including but not limited to moderate subsidies, tax rebates, and encouraging financial institutions to provide low-interest loans for green transformation projects; at the same time, provide professional talent training support for enterprises, thereby reducing the cost and risk of enterprise transformation.

1. Analysis of global climate governance and new regulatory requirements for globalization of Chinese companies

Recently, the international community and governments have generally strengthened their cooperative efforts in climate governance and environmental protection. China companies going abroad need to continuously improve their carbon management capabilities at all levels to better cope with different regulatory compliance requirements and the changing policy landscape.

1.1. The EU's pioneering carbon tariffs drive changes in international economic and trade rules

The EU, as an important destination for China companies going abroad, has proposed the "Fit for 55" package of legislation under the European Green Deal as a concrete path to achieve its goals. Among them, the EU Carbon Boundary Adjustment Mechanism (EU CBAM) has the significant impact on Chinese enterprises. EU CBAM plans to impose "carbon tariffs" on goods imported into the EU in the form of quotas to prevent carbon leakage and avoid jeopardizing the integrity and effectiveness of its climate policy.

Policy Overview

EU Carbon Border Adjustment Mechanism (EU CBAM)	
Legislative Process	The EU Council voted to pass the CBAM in April 2023, and the entire legislative process has been completed.
Effective Date	Transitional Period: October 1st, 2023 – December 31st, 2025 Definitive Period: Starting from January 1st, 2026
Scope of Application	Iron & Steel, Cement, Aluminum, Fertilisers, Electricity, and Hydrogen
Impact on Chinese overseas Enterprises	A new global climate governance order, led by developed countries, "bases on regulation" and centered around "carbon markets and carbon tariffs" is gradually taking shape. The "carbon tariffs" such as CBAM starts to directly impact on Chinese export trade, especially carbon-intensive export industries. This poses significant challenges for sectors such as steel and aluminum, where China has a substantial export volume.

Figure 1 Overview of the *EU Carbon Border Adjustment Mechanism* (EU CBAM)

The implementation of the EU CBAM will significantly influence the international trade pattern. As a border mechanism to regulate international trade, other countries are likely to follow the EU's pace and establish similar "carbon tariff" mechanisms.

1.2. Increased sustainability requirements throughout the product life cycle

As the international community gradually transforms from a linear economy to a circular economy, regions such as the EU have successively introduced policies and

systems related to the circular economy system as well as mandatory disclosure requirements related to the products carbon footprint.

On March 11, 2020, the European Commission released the new Circular Economy Action Plan (CEAP), which for the first time proposed a comprehensive product policy framework, integrating the concept of circular economy throughout the entire life cycle of product design, production, consumption, repair, recycling, and secondary energy resource utilization for sustainable management of products.
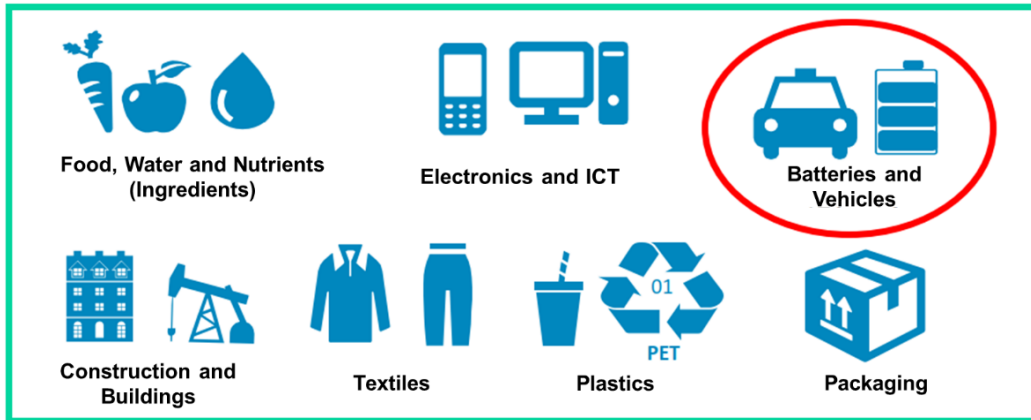

Figure 2 The 7 Key Product Value Chains Prioritized by the EU *Circular Economy Action Plan*

In June 2023, the European Parliament adopted the New EU Battery Regulation, which requires all batteries entering the EU market as well as batteries produced locally in the EU to comply. For light means of transport (LMT) batteries, industrial batteries with a capacity greater than 2kWh and electric vehicles batteries, companies will be required to provide the Product Carbon Footprint (PCF) declaration and label.

New EU Battery Regulation	
Legislative Process	The European Parliament passed the "New EU Battery Regulation" on June 14th, 2023, and the entire legislative process has been completed.
Effective Date	Came into force on August 17th, 2023
Scope of Application	• This Regulation applies to all categories of batteries, namely portable batteries, starting, lighting and ignition batteries (SLI batteries), light means of transport batteries (LMT batteries), electric vehicle batteries and industrial batteries • Regardless of their shape, size, weight, design, material composition, chemistry, use or purpose. • Regardless of whether they were produced in the Union or imported. • It shall also apply to batteries that are incorporated into or added to products or that are specifically designed to be incorporated into or added to products.
Impact on Chinese overseas Enterprises	For Chinese overseas enterprises, exported battery products must meet the requirements of the "New EU Battery Regulation," providing a Carbon Footprint (PCF) declaration and label to enter the EU market.

Figure 3 Overview of the *New EU Battery Regulation*

In March 2022, the European Commission adopted the proposal for an *Eco-design for Sustainable Products Regulation* (ESPR). Extending the scope of the Eco-design Directive to all products except food, feed, and pharmaceuticals.

Policy Overview

Eco-design for Sustainable Products Regulation (ESPR)	
Legislative Process	The European Commission proposed the ESPR in March 2022 Committee on the Environment, Public Health and Food Safety(ENVI) of the European Parliament passed the amended draft of the proposal in June 2023.
Scope of Application	All products (except food, feed, medicinal products, living organisms).
Impact on Chinese overseas Enterprises	Enterprises going global need to consider the low-carbon sustainability of the entire product life cycle starting from the product design phase. Products exported to the EU will need to establish a "Digital Product Passport".

Figure 4 The EU *Eco-design for Sustainable Products Regulation* (ESPR)

Under the regulatory trend oriented towards a circular economy, companies going abroad to developed markets urgently need to pay attention to the requirements, such as product life cycle management, carbon footprint disclosure, and traceability of products carbon footprints. They should also consider the environmental and social impacts of products throughout their life cycle, realize efficient use of resources, and reduce carbon emissions and wastes, to satisfy the access standards of different countries and regions.

1.3. The transition from voluntary to mandatory sustainability information disclosure

As investors, consumers and stakeholders become more concerned about corporate sustainability performance, sustainability disclosure is gradually shifting from voluntary to mandatory. For example, the *European Union Corporate Sustainability Reporting Directive* (CSRD) and the *European Union Sustainability Due Diligence Directive* (CSDDD) have transformed sustainability disclosure, especially carbon emission-related indicators, into mandatory compliance requirements and extended the scope of disclosure from the enterprise itself to the upstream and downstream of the supply chain.

EU Corporate Sustainability Reporting Directive (CSRD)	
Legislative Process	Council of the EU Press release November 2022, and the entire legislative process has been completed
Effective Date	The CSRD officially came into force in December 2022 Member States have 18 months to transpose the provisions into national law.
Scope of Application	• The CSRD classifies a large company as one that meets two out of three of the following criteria: (1) More than 250 employees; (2) A turnover of over €40 million; (3) Over €20 million total assets. • Applies to companies listed on regulated markets in the EU (apart from listed micro-enterprises), large companies, and Listed SMEs, • Applies to non-EU companies with a net turnover of €150 million in the EU, and with at least one subsidiary or branch in the union.
Impact on Chinese overseas Enterprises	The CSRD has more detailed disclosure requirements and a broader scope of disclosure information, which will significantly increase the regulatory costs for exporting enterprises within its scope. Additionally, as the CSRD requires the disclosure of value chain information, related upstream and downstream enterprises in the supply chain will also need to comply with their obligations and disclose ESG information in accordance with regulations. Furthermore, the independent assurance mechanism introduced by the CSRD also sets stricter requirements for the quality of corporate sustainable information disclosure.

Figure 5 The EU *Corporate Sustainability Reporting Directive* (CSRD)

EU Corporate Sustainability Due Diligence Directive (CSDDD)	
Legislative Process	The European Commission published the CSDDD proposal in February 2022, and the European Parliament voted to pass the proposed CSDDD in June 2023.
Effective Date	The CSDDD was adopted in 2023.The negotiation period is expected to finish by 2024 and will be transposed to domestic laws by EU member states by the end of 2026.
Scope of Application	The CSDDD will apply to both EU and non-EU enterprises, including: • EU companies: (1) with more than 500 employees and a net global turnover of more than € 150 million, or (2) or which operate in specific high-impact sectors with more than 250 employees and a net global turnover of € 40 million. • Non-EU companies: (1) generate a net turnover of more than € 150 million in the EU in the last financial year, or (2) generate a net turnover of more than € 40 million in the EU, provided at least 50% of worldwide turnover was generated in a high-impact sector.
Impact on Chinese overseas Enterprises	Compliance with sustainable due diligence will become a "threshold" that Chinese enterprises must cross to enter the EU market. Enterprises within the scope, as well as related upstream and downstream supply chain enterprises, will need to conduct supply chain due diligence in accordance with regulations, take preventive and remedial measures, and identify and prevent potential human rights and environmental risks in their business activities early on, to achieve sustainable supply chain compliance.

Figure 6 The EU *Corporate Sustainability Due Diligence Directive* (CSDDD)

China companies going abroad increasingly need to take supply chain carbon management as an important part of their strategic development planning, and continuously improve the level of supply chain carbon management, to maintain strong comprehensive competitiveness under the strict carbon management regulatory compliance requirements.

2. Analysis of challenges faced by China companies under new climate governance requirements

To meet global compliance policy requirements and under the guidance of China's Carbon Peaking and Carbon Neutrality Goals, green transformation has gradually become a must for China companies going abroad. The challenges faced in this process are mainly in the areas of strategy and management, as well as data and application.

2.1. Strategy and management

- **Balancing "business development" and "carbon reduction":** Affected by global economic shocks, geopolitical conflicts, and other factors, the business growth of companies going global faces significant challenges. Green transformation cannot be achieved without the investment of professional talents, capital, and technology, including tracking, and analyzing policy trends, purchasing environmentally friendly equipment, and developing green products. Therefore, how to achieve green transformation while maintaining business growth is a major challenge for enterprises.
- **Insufficient carbon risk identification and control capacity:** With the deepening of global policies and actions to address climate change, China companies going abroad need to cope with uncertainties in policy systems, product standards, supply chain requirements, etc. Influenced by these dynamic factors, there are two main challenges in the field of carbon risk management. One is the failure to identify and avoid carbon risks in time due to the lack of knowledge and experience related to sustainable development and the misunderstanding of climate policies by corporate management. The other is the insufficient competency to identify long-term and systemic carbon risks, leading to inaccurate recognition and control of them.
- **Inadequate carbon governance structure:** Carbon management awareness and responsibilities should penetrate all levels of an enterprise governance structure to incentivize internal stakeholder groups to achieve a unified carbon reduction target. In terms of organizational structure and processes, many enterprises have not yet established and implemented specific departments or teams for carbon management. Even in some enterprises that have set up relevant departments or teams, there is a situation where personnel from multiple departments are responsible for carbon management. This poses challenges in terms of manpower and resource allocation for enterprises to strengthen carbon monitoring and reporting, meet compliance requirements, and formulate risk response strategies.
- **Incomplete coordination mechanisms within enterprises**: Integrating carbon management into all aspects of an enterprise's operation and management is one of the most important strategies for achieving sustainable development and addressing carbon risks. In carbon emission accounting, the relevant activity data involves all aspects of the enterprise's operation and management, and these data are usually counted and managed by different departments. Without effective collaboration and management mechanism, it is impossible to form a unified summary

caliber, and it is more difficult to regularize the carbon data and ensure its quality and completeness.

- **Limited upstream and downstream value chain synergies**: The global climate policy trend is gradually expanding from corporate carbon emissions to upstream and downstream supply chain carbon emissions. More and more companies are requesting carbon footprint data from their suppliers due to regulatory and supervisory requirements. And they are setting up carbon footprint targets for suppliers to minimize the risk of value chain compliance. In addition, most enterprises only focus on Scope 1 and Scope 2 emissions, and seldom consider the carbon neutrality of the whole value chain. Although some enterprises have made requirements for suppliers to use 100% green electricity and include the carbon footprint of raw materials in evaluation indicators, supply chain decarbonization often requires the leading enterprise to drive, as well as efforts from supply chain enterprises to improve their digitalization or carbon footprint calculation. It requires a large investment, therefore making supply chain decarbonization difficult to truly implement.

2.2. Data and application

- **Insufficient data transparency:**
  - **Inconsistent carbon emission calculation standards:** The supply chains of most going abroad companies span several countries and regions, involving multiple links and participants. However, due to the differences in technologies, standards, processes, and cultures related to carbon accounting for data collection and sharing, there is a common problem of low transparency and lack of comparability in the data within the supply chain. Companies going abroad cannot obtain accurate and comprehensive information and data related to carbon emission calculations from their suppliers, making it difficult to fully understand the scope of data collection, system boundaries, data sources, etc., and thus unable to integrate upstream and downstream carbon emission data.
  - **Concerns about data security:** Some enterprises are reluctant to disclose their carbon emissions data in the absence of data security protection, especially when sensitive business information is involved. This limits the access of overseas enterprises to value chain data, which affects their ability to accurately account for the carbon footprint of their products in turn. This limits the data that enterprises going global can obtain, affecting the accounting accuracy of product carbon footprints.

- o **Incomplete data reporting:** Some enterprises have not established a comprehensive reporting mechanism or incentives to prompt suppliers to disclose their carbon emissions data. The transparency of carbon management data within the value chain is insufficient, leading to incomplete or missing carbon management data, which restricts the accuracy of product carbon footprint accounting.
- **Limited data traceability**: In complex supply chains, the raw materials, production processes and distribution channels of products often involve multiple players from different countries or regions. However, the carbon footprint of a product is often difficult to trace back to specific players and segments due to a lack of data sources documentation. At the same time, when companies going abroad rely on multi-tiered suppliers, they may have difficulty in tracing the origins of materials and components used in their products. Such traceability difficulties make it challenging to calculate the carbon footprint at each stage of the value chain.
- **Unclear technological path to support green transformation:** Green transformation requires enterprises to have the corresponding technology and capabilities. The weak technical capabilities of some companies make it difficult to carry out carbon verification, energy saving and emission reduction.
  - o From a product design perspective, 80% of the environmental impact factors of a product are determined during its design stage. It is necessary to balance the economic, functional, reliable, and sustainable indicators from the whole life cycle. And the products' key performance data needs to be designed and simulated, which requires advanced technology. Currently, most enterprises have room for improvement in this area.
  - o From the perspective of manufacturing, traditional high-energy-consuming and high-polluting industries such as steel and chemical industries, as well as leading industries in overseas business such as batteries, electronics, and new energy, all have high-carbon energy structures and complex process flows. Although many enterprises have technology application experiences in data collection and production management, the efficiency and quality of production line, process, and energy management still need to be improved.
  - o From the perspective of electrification, there is a lack of management tools for many dispersed electrical equipment, making it difficult to operate and maintain them remotely. It is also challenging to monitor the operating conditions of equipment in the

distribution network in real-time, affecting the efficiency of equipment management.

o From the perspective of buildings, the intelligent control and management of the internal facilities and systems of buildings, as well as the operating efficiency, safety, comfort, energy saving, and environmental protection level of buildings still have great room for improvement.

o From the perspective of supply chain, due to the concerns about data security and inconsistencies accounting standards between upstream and downstream, etc., the carbon data on the value chain is not transparent, and its precise data to support the carbon emission calculation and monitoring of upstream and downstream enterprises.

3. Harnessing the "Dual Drivers" of digitalization and decarbonization to empower China companies going abroad

To cope with the above challenges, companies going abroad should formulate a sustainable development strategy according to their situation, closely integrate it with their business development strategy, actively respond to the challenges, identify, and grasp the development opportunities, balancing the contradiction between "development" and "carbon reduction". Build an internal governance system to ensure the implementation of the sustainable development strategy from top-level design to bottom-level implementation. The key lies in the "Dual Drivers" of digitalization and decarbonization to break through the situation and drive the green transformation of the whole value chain based on the end-to-end data base, to empower Chinese enterprises build green going abroad path.

3.1. End-to-end data foundation

Enterprises need to start with a precise verification of their carbon emissions baseline as the data base for formulating their own carbon peak and carbon neutral development strategies. Taking the mobility industry as an example, digital solutions can provide companies with reliable product and organizational carbon emissions data, identify carbon emission hotspots, and thus unleash carbon reduction potential.

In the mobility industry, due to the long carbon footprint accounting process, large data volume, and complex calculations, companies going abroad still face difficulties and challenges in accurately and automatically calculating their product carbon footprints. Through the application of digital technology, it can effectively solve the pain points such as difficulties in scientifically constructing carbon reduction strategic paths and strategies, and the lack of product-level carbon emission data bases, etc. For instance, an automotive enterprise's body side product manufacturing plant has deployed a product carbon footprint digitalization solution

through cooperation with Siemens to gradually promote credible actuarial calculation and traceability of the carbon footprints of the whole plant's products:

- **Accurate, efficient and automated quantification of carbon emissions of the manufacturing processes**: Relying on edge computing technology, product-related carbon emissions data are automatically collected from Energy Manger Pro, MES, and other IT and OT systems in the factory, and accurately decomposed through modeling.

- **Trusted and secure exchange and sharing of product- related carbon emission data throughout the supply chain:** without disclosing sensitive information, secure, safe, and trustworthy exchange and share of raw material carbon emission information from suppliers can be realized.

- **Vehicle Body Side Product Carbon Twin:** Visualize the product carbon footprint; multi-dimensional data analysis and visualization, assisting in monitoring the trend of product carbon emissions, and providing data support for carbon reduction path planning and carbon reduction strategy designation.
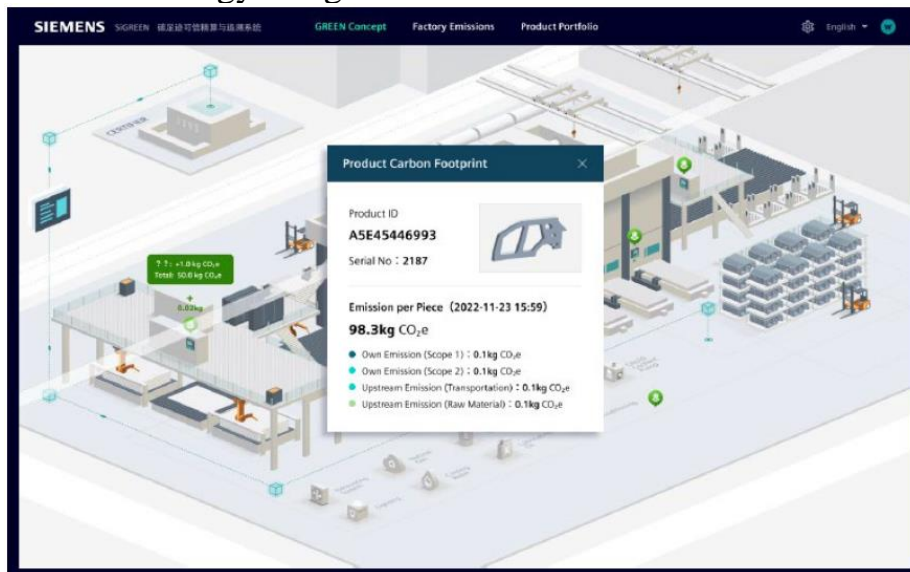

Figure 7 Application Case of Automotive Enterprise Product Carbon Footprint Digital Solution

3.2. Green transformation of the entire value chain

3.2.1. Green product design

Product Research and Development (R&D) is the starting point of the whole product life cycle, and green product design is the source of the enterprises' green transformation, which is of great significance for carbon reduction.

To help enterprises in green product design, product development and design software platforms need to provide a product- oriented "sustainability" design module, which helps users to complete the product design, and at the same time, calculate and summarize the carbon emission data of each part and the water

consumption data. Based on the current design, engineers can therefore obtain the entire product's carbon emissions and carbon credit data during the design stage.

Green design is also about improving material utilization and reducing material consumption. Enterprises need to optimize them at the design phase: using Generative Design tools and 3D printing solutions to reduce raw material waste, improve production efficiency, reduce parts inventory and financial pressure. Secondly, it is necessary to fully utilize existing parts rather than redesigning new parts. The use of existing mature product parts can reduce resources and costs waste caused by product verification, mold redesign, re-procurement, etc. during the design phase. It is also one of the elements of decarbonization and green product design. Finally, simulation, emulation, and verification in the digital world through digital twin technology ensures a balanced development of product reliability, functionality and economic indicators while achieving sustainability targets in the real world.

Advanced solutions and successful cases in the market such as industrial software NX and Geolus solution based on NX platform, in the product development and design of new energy vehicles, wind power equipment, photovoltaic equipment, solar energy equipment, etc., by some outstanding enterprises, such as BYD, Gotion High tech, Shanghai Electric Wind Power Group, China State Shipbuilding Corporation Haizhuang Windpower, CRRC Shandong Wind Power, etc. These successful references in the product green R&D, simulation, data management, 3D printing, etc. should be scaled up quickly.

3.2.2. Green production and manufacturing

The key to green production and manufacturing lies in the transparency of energy and production data and the continuous optimization for higher efficiency. In this section, we will take energy management, mechanical processing, and sustainability in the process industry as examples.

3.2.2.1. Energy efficiency management and continuous optimization

To achieve high energy efficiency in the manufacturing process, improve energy efficiency and reduce environmental impact, real-time energy consumption data analysis and energy management optimization are required. Enterprises need to deploy digital energy management tools and solutions, combined with Artificial Intelligence (AI) and other cutting-edge technologies, which can automatically collect real-time energy consumption data and conduct transparency analysis of factory energy consumption, monitor and manage information on energy consumption, factory output, and equipment operation status during the production process, identify possible energy saving and emission reduction opportunities, and predict potential equipment failures, to achieve the dual goals of cost savings and environmental protection.

Siemens Industrial Automation Products Ltd., Chengdu (SEWC) was awarded the World Economic Forum's "Sustainable Lighthouse" in 2023. SEWC has realized a "win-win" in terms of economic and environmental benefits through the full deployment of the digital energy product Energy Management, reducing energy consumption per unit of product by 24% and waste per unit by 48%, while increasing production volume by 92% between 2019 and 2022.

3.2.2.2. **Energy-efficient digital machine**

Machine tools that are widely used in machining process often require high investment, the availability and efficiency of machine tools have a significant influence on the resource efficiency of materials processed and energy efficiency of the process.

Machine tools manufacturers and users need to dynamically optimize and eliminate uncertainty and uncontrollable factors in the machining process, comprehensively improve the cutting performance and machining efficiency and achieve early prediction and warnings of tools damage, while improving operation safety and reducing additional processing costs and maintenance costs. The ACM Suite helped improve production efficiency by 7%, saving approximately RMB60,000 in production costs and 15,000 kWh of power consumption per machine annually, thus effectively boosting resource.

3.2.2.3. **Sustainability in the process industry**

Establish digital lab at the new product and new process development phase to build process models of synthetic reactions by means of mathematical models and computer simulations, optimize the R&D routes, reduce material losses, and accelerate innovation and R&D.

At the plant design stage, the optimization of energy consumption of the entire production system, the recycling of by-products, and the recovery and reuse of wastes should be considered comprehensively, so that the plant and the supply chain need to be redesigned for the perspective of green production and low carbon. To use process simulation and optimization software such as gPROMS can carry out integrated process- engineering design to fundamentally upgrade the entire production system in a green and low-carbon way. To establish virtual production lines through digital twin platforms such as gDAP can effectively validate the production strategy and anticipate the product quality and material consumption at the design stage. To deploy Real Time Optimizer (RTO) with Adaptive Models (AI), can sense the status of the production system and develop green and low-carbon production strategies throughout the entire design space exploration.

In the production stage, the online production and predictive systems can stabilize and optimize production simultaneously. By improving product quality and yield, reducing energy and material consumption per unit of production, and thus

reducing the carbon footprint of the entire production system, the real-time online system can ensure continuous optimization and precise production control.

3.2.3. Sustainable electrification transformation and smart infrastructure

3.2.3.1. Sustainable electrification transformation

The reliable operation of electric energy is a prerequisite for enterprises to reduce their own carbon footprints and is an integral part of urban infrastructure. Among them, the distribution network plays a very important role. However, for the operation and maintenance of enterprises after going abroad, they also face many challenges, including the lack of efficient management for many dispersed equipment, the lack of a unified and efficient real-time energy monitoring platform as well as a reasonable energy efficiency assessment method, the inability to real-time operating conditions of the distribution network equipment, and difficulties in remote operation and maintenance, etc.

To address these challenges, enterprises can achieve smart Operation and Maintenance (O&M) and low-carbon management by deploying one-stop smart distribution management solutions, including:

- **Real-time transparency**: Connecting underlying sensors, data collection units, intelligent online monitoring devices and other digital applications, provide real-time operating status monitoring, conduct efficient asset management, reduce product life cycle costs, and optimize asset investment.
- **Energy monitoring**: By reviewing the energy consumption status, combining the product output with the energy consumption situation, determine the KPIs of the core equipment. After calculating the benchmark value and the baseline value, continuously optimize the level of energy consumption and reduce carbon emissions for users.
- **Efficient operation and maintenance:** Real-time early warning of equipment failure through monitoring and analysis, and set the maintenance plan in the system process, realizing the transformation from planned maintenance to predictive maintenance, reducing the probability of equipment damage, and making the operation and maintenance management system more proactive and efficient.

For example, a domestic airport terminal building has applied Siemens Panel Manager, to digitize the on-site power distribution room level by adopting digital power distribution solutions and green low-voltage electrical products to support the airport's intelligent operation and maintenance and low-carbon management.

3.2.3.2. Smart buildings

Companies going abroad should seize the opportunity to combine digitalization and intelligence and introduce smart buildings as a solution for energy saving and

carbon reduction in buildings, thereby reduce their carbon emissions. When transitioning to smart buildings, enterprises can refer to the following solutions:

- **Equipment interconnection and automation**: Utilize sensors and the IoT technology to interconnect internal equipment and systems of buildings and collect real-time equipment data. Based on the collected data, implement automated control systems, such as automatically adjusting lighting, air conditioning, heating, and other equipment, thereby improving energy efficiency.
- **Digital power monitoring system**: collects real-time data, analyzes energy consumption patterns and trends, identifies energy waste points, provides accurate data support for energy management decisions, and promotes enterprises to implement energy management according to ISO50001.
- **Intelligent environment adjustment and office layout**: Employees can customize the environmental settings of their workspaces through smart devices, providing a better office environment. Based on real-time data, the system analyzes the distribution of employees and optimizes the office layout to ensure the comfort and convenience of employees

For instance, in the Mechanical and Electrical industry, as one of China's major export-oriented industries, how to follow the "Belt and Road" to explore overseas business opportunities has become a question that many electromechanical enterprises must think about in the face of increasingly fierce competition in the domestic market. Lockemason is an enterprise trying to transform. The "Zero-Carbon Smart Factory" in Jinan has realized real-time monitoring of the factory's energy consumption and carbon footprint. By introducing cutting-edge technologies from Siemens and other companies, the company adopts ECX, a smart energy carbon management platform, to realize real-time monitoring of the energy consumption and carbon footprint of the factory. MGMS, a smart microgrid management platform, is implemented to realize a 100% green substitution of the factory's energy consumption which can carry out real-time management and scheduling of new energy systems such as photovoltaic, energy storage and charging poles. They also use SC Insights X, an intelligent park management platform, to realize the integration and unified management of all the intelligent systems in the factory, which can enhance the efficiency of the factory's operation and management.

Figure 8 The Zero-Carbon Smart Factory of Lockemason

3.2.4. Green supply chain management

Supported by accurate data collection, monitoring and carbon footprint accounting, digital technology can effectively manage the influencing factors of carbon emissions in the supply chain and coordinate upstream and downstream enterprises to take carbon reduction actions. The following are the digital low-carbon supply chain management solutions that enterprises can refer to and apply:

- **Digital supply chain management system:** use sensors, IoT technology, etc., to monitor energy consumption and carbon emissions in the supply chain in real time.
- **Digitalized Supplier Evaluation and Management Mechanism**: Introduce environmental evaluation indicators into the supplier evaluation system, use digital technology to track suppliers' real-time environmental performance, and establish a digitalized risk management mechanism to assess suppliers' environmental and social risks.
- **Digital Logistics Management**: Optimize logistics network and logistics capabilities with digital technology.

For China companies going abroad, they need to correctly identify and effectively track the carbon emission hotspots and reduction potentials in each segment of their own value chains, to achieve collaborative decarbonization within the value chain. This section will illustrate how digital solutions help industrial enterprises build cooperative ties within the value chain and facilitate the decarbonization process, taking the chemical industry as an example.

The chemical industry, as a key industry with high energy consumption and high pollution, requires consistent accounting methods, transparent and trustworthy

value chain data interaction, and upstream and downstream coordinated carbon management for decarbonization. The development of digital solutions for enterprise carbon management requires efficient data interaction between the China companies going abroad, their upstream and downstream and third-party verification organizations. It is beneficial to realize the transparency of carbon footprints and efficient collaboration between the upstream and downstream enterprises within the value chain, and at the same time, effectively improve the truthfulness, accuracy, and comprehensive acceptance of the data related to carbon emissions. Together for Sustainability (TfS) is an industry-leading initiative promoted by the chemical industry, in which 47 member enterprises have fully deployed digital carbon footprint solutions by collaborating with Siemens and other companies. Based on the exchanged data and their own carbon emissions, they establish a climate-neutral value chain, promoting and accelerating the low-carbon transformation of the entire chemical industry through high-quality integration of carbon emissions across the value chain.
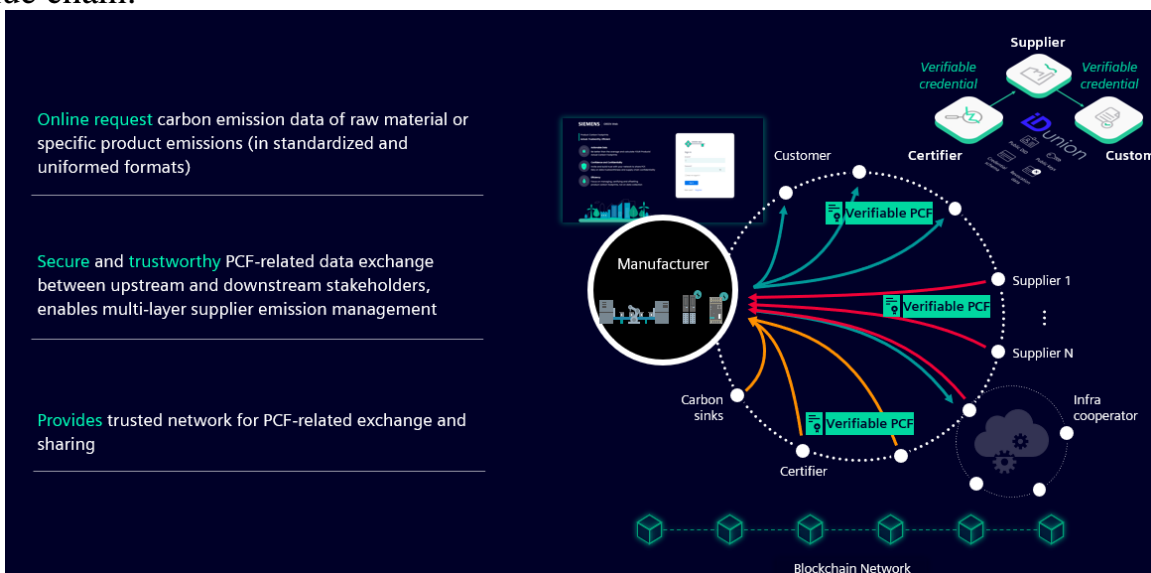

Figure 9 Secure and reliable sharing of supply chain carbon emissions data and collaborative ecosystem

4. Policy recommendations

By providing a richer range of products, technologies, and solution support for Chinese manufacturing enterprises, particularly those targeting overseas markets, we can provide positive incentives for green transformation, reduce transformation costs, and lower the risks associated with it. Thus, we will promote the industry to develop more environmentally friendly and sustainable and facilitate the green and decarbonization transformation while conducting business in the target markets smoothly.

4.1. Refine regulatory, assessment and market mechanisms, enhance standard framework

A series of policies have been introduced to promote the green transformation of enterprises. However, the standardization and standard framework related to data and applications such as standards, certifications, carbon emission accounting, and carbon trading market, still require improvement. The government could take the lead to further improve carbon regulation and evaluation mechanisms and collaborate with reputable industry organizations to assess the progress of enterprises' green and decarbonization transformation as well as their environmental performance. This includes further refining of emission standards and requirements for emission reductions, conducting environmental audits and assessments, and improving the mechanisms for carbon market pricing and transactions. These measures will encourage enterprises to fulfil their environmental responsibilities and achieve sustainable development. Industry-oriented improvements to green product standard systems and environmental certification mechanisms will enhance the international reputation and market competitiveness of enterprise products. Efforts should also be made to establish a series of standard frameworks for pollution reduction and carbon emission reduction in key industries, as well as environmental information disclosure standards for industrial enterprises, assisting China companies going abroad in improving the quality of carbon data disclosure in the industrial sector. Introducing third-party certification organizations with international reputation is beneficial for China companies to meet the international green certification requirements.

4.2. Promote cooperation among diversified domestic stakeholder, deepen international cooperation

Domestically, establish an effective cooperation mechanism among governments, enterprises, research institutions, industry associations, and social organizations. This can be achieved through government-led joint working groups, industry organizations composed of enterprises and scientific research institutions, intra-industry exchange activities and enhanced information-sharing, to promote the advancement and implementation of green and low-carbon transformations. Externally, actively participate in international climate governance, exchange experiences in green development, strengthen technology and information exchanges, enhance cooperation on low-carbon development, and promote the establishment of mutually recognized carbon accounting standards and systems. Take the new energy and other export-oriented industries as a starting point to promote the alignment of Chinese green standards with international standards, encourage various types of market entities to get involved in standard setting, and provide enterprises with opportunities and platforms for international cooperation.

4.3. Strengthen financial, fiscal and talent support, establish demonstration and promotion mechanisms

Provide extensive financial support for enterprises' green transformations to help them reduce transformation costs and risks based on the carbon reduction performance, including providing moderate subsidies or green export rebates, providing subsidies and rewards for adopting low-carbon products and technologies, and encouraging financial institutions to give low-interest loans for green transformation projects, to alleviate cost and risk of enterprises' green transformation. Governments or industry organizations could take the lead in providing training and capacity-building projects for green transformation and overseas business, helping enterprises to improve their low-carbon development levels and adapt to the standards and demands of target markets, including a broader range of technical consulting, technical training, professional certification, and talent introduction. It is encouraged for cities and industrial parks to select key industries for China companies going abroad to carry out pilot demonstration projects for enterprise carbon reduction, select a batch of successful cases that have achieved carbon reduction and promoted overseas business growth, and promote their successful solutions in the industry.

5. Conclusion

The joint response to climate change has become a global consensus, and the inevitable trend of changing regulation environment and accelerated decarbonization pace presents new challenges and opportunities for China companies going abroad. These companies should fully leverage digital technology to empower their green transformation, accelerate adaptation to the continuous development of carbon management and policy systems both domestically and internationally, and explore broader space for their business development.

Through the "Dual Drivers" of digitalization and decarbonization, Siemens will utilize digital innovations and cross-industry expertise, co-create a green ecosystem with all partners in China to help build end-to-end zero-carbon industrial chains to empower China companies going abroad in a green path.