基于柔性用电的建筑绿电消费认证机制与虚拟电厂模式研究

Research on green power consumption certification mechanism and virtual power plant based on energy flexible buildings

深圳市建筑科学研究院股份有限公司

2022 年 10 月

Shenzhen Institute of Building Research co., Ltd

October, 2022

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致谢

本项目由深圳市建筑科学研究院股份有限公司承担，由能源基金会提供资金支持。

本项目是能源基金会低碳城市项目组下的课题，课题编号: G-2019-33440。

在本项目研究过程中，研究团队得到了深圳供电局有限公司、中国建筑节能协会等合作机构的大力支持，得到了来自建筑和电力两个行业的专家学者的鼓励和帮助，在此向他们表示诚挚感谢。

关于项目单位/关于能源基金会

深圳市建筑科学研究院股份有限公司（简称"建科院"）是国家级高新技术企业、全国博士后科研工作站、全国绿色建筑先锋单位、国家绿色建筑华南基地、全国科普教育基地，以中国绿色城市价值创造者为使命，2000 年以来专注于持续探索中国特色新型城镇化之路。建科院的愿景是平视城市，共享生命精彩。

能源基金会是在美国加利福尼亚州注册的专业性非营利公益慈善组织，于 1999 年开始在中国开展工作，致力于中国可持续能源发展。能源基金会的愿景是通过推进可持续能源促进中国和世界的繁荣发展和气候安全。

前言

在碳中和、碳达峰的背景下，建筑领域和电力领域都面临着转型的压力。在建筑领域，城市的高容积率、高负荷密度特征决定了城市建筑周边的可再生能源非常有限。叠加城市经济快速发展导致的用能需求增长势头，大多数城市建筑无法依靠自身节能和屋顶光伏实现碳平衡，在深度脱碳的路径上陷入困局。在电力领域，随着用电负荷峰值连年增长和峰谷差不断拉大，叠加风光电等波动性能源并网规模的不断增加，电网调峰压力越来越大，迫切需要引入大量灵活可调资源。

从节能到柔性的思维转变是破局的关键。从建筑角度，如果只局限在建筑红线内对建筑能源系统做优化，很难实现碳中和目标；而上升到城市整体层面，电网可以为建筑提供更丰富零碳电力资源和更可靠的电力供应保障，而且整体方案的社会总成本更低。从电网角度，未来高比例风电的渗透会到来灵活性资源的紧缺，建筑中的空调、热水、充电桩等可调节负荷是未来可挖掘的用户侧灵活性资源。柔性用电可以促进建筑和电网的携手低碳发展。

本项目围绕着通过柔性用电促进建筑和电网携手低碳发展的主题，结合虚拟电厂的发展现状，对基于柔性用电的虚拟电厂模式和绿电消费认证机制开展研究，分析了虚拟电厂在实现建筑与电网互动中的作用，比较了建筑柔性负荷的优劣势，指出了建筑虚拟电厂脱“虚”向“实”的发展方向，开展了建筑负荷调节能力的测试分析，提出了绿电消费认证机制的建议。

本项目于 2021 年 11 月在能源基金会立项，执行期 1 年，于 2022 年 10 月结题。项目研究工作得到了深圳供电局有限公司、中国建筑节能协会等合作机构的支持，得到了来自建筑和电力两个行业的专家学者的鼓励和帮助。项目研究成果支撑了直流联盟年度报告《携手零碳——建筑节能与新型电力系统》的出版、《深圳市零碳建筑评价标准》的立项、南方电网科技项目《面向大规模可再生能源消纳的城市建筑与电网互动关键技术研究与应用》和《电网友好型零碳建筑关键技术研究和集成应用》的开展。

执行摘要

■ 建筑和电网如何携手低碳发展？

- **建筑需要在节能的基础上进一步减碳。**建筑领域正在从能耗“双控”向碳排放总量和强度“双控”转变，低碳发展成为新的发展方向。电力是建筑能源消耗的主要形式，其在建筑终端用能中的占比已经接近 50%。为了实现建筑运行的低碳化，需要提高绿电消费比例，降低建筑电力碳排放。然而，城市高容积率、高负荷密度特征决定了城市建筑周边的可再生能源非常有限，再叠加城市经济快速发展导致的用能需求增长势头，大多数城市建筑无法依靠自身节能和屋顶光伏实现碳平衡。在节能基础上，建筑如何进一步减碳是城市低碳发展面临的问题。
- **风光并网趋势下电网调峰需求日益增长。**当前，电网面临 100 小时的负荷尖峰问题。2021 年夏季，全国多地经历了持续高温天气，空调使用需求激增，叠加疫情后工业生产复苏，多地用电负荷也创下了历史新高，很多地区都出现了电力供需偏紧的现象，不得不通过有序用电来保障电力供给平衡，甚至拉闸限电的极端措施也时有发生，对工业生产、居民生活都带来了困扰。未来，电网调峰需求进一步增长。随着风光电并网规模的增加，电力紧张和电力盈余往往会以天为周期甚至更短时间为周期反复出现。电力系统的调峰需求不再局限于 100 小时的负荷尖峰，而可能随机广泛分布在全年 8760 小时。电力系统需要大量调峰和储能设施，能够在风光出力偏小的时候填补电力缺口，在风光出力偏大的时候储存过剩电力。电网调峰需求的增长为灵活性资源的发展创造了机会。
- **柔性用电成为建筑和电网携手低碳的契合点。**从建筑角度看，如果局限在红线内对建筑能源系统做优化，有限的资源和高昂的储能成本使得碳中和目标难以实现。利用电网连接丰富零碳电力资源、获取更可靠的电力供应保障，建筑领域能够以更低成本的方式减碳。从电网角度看，建筑中的空调、热水、充电桩等可调节负荷是潜力巨大的灵活性资源。挖掘建筑中的灵活性资源有助于解决日益增长的调峰需求，促进风光等波动性可再生电源的发展。建筑基于柔性用电为电网提供大量低成本的调

节资源，以帮助电网解决调峰问题；相应地，电网给建筑提供更高比例的绿色电力，以帮助建筑实现电气化和低碳化。以柔性用电为契合点，建筑领域和电力领域可以携手低碳发展。

- **建筑节能的思维转变：能效和灵活性的双提升。**基于柔性用电的建筑和电网携手低碳的模式改变了建筑节能的传统思维。以前，建筑节能关注总电量的减少，不同时间节电没有区别；未来，电力市场和绿电交易市场将帮助人们发现不同时间用电的经济成本差异和绿电占比差异，即使同样节省一度电，但是因为发生时间不同而产生不同的经济效益和减碳效益。在峰谷电价差 4 倍以上的地区，节约高峰时期一度电的效益比节约低谷时期四度电的效益还多。能源效率将不再是唯一的节能指标，可调节能力也将得到重视。

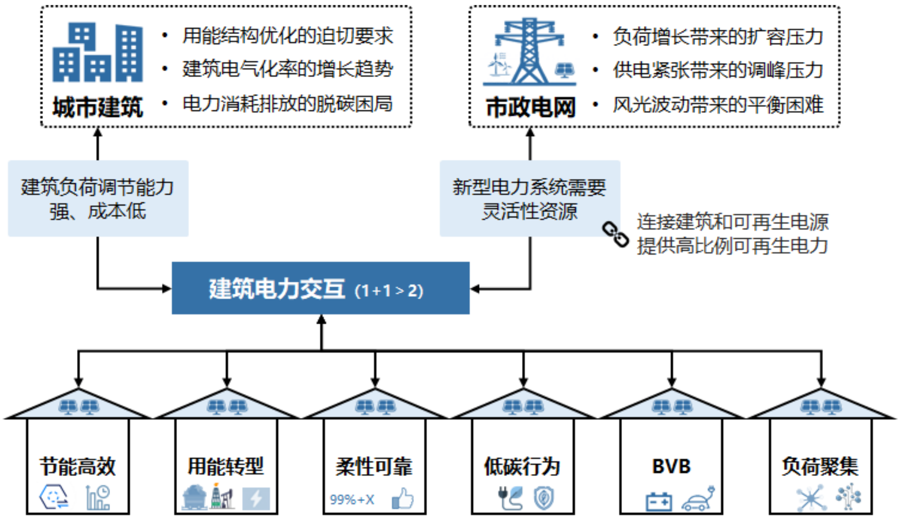

图 I 基于柔性用电的建筑与电网携手低碳模式

■ 虚拟电厂实现建筑与电网的柔性互动

- **建筑负荷应该先聚集，再与电网进行交互。**首先，由于管理需要，电力系统发布的调节产品类型，无论是需求响应、可中断负荷、一次调频、二次调频、还是调峰等，都有最低容量要求和调节性能要求。建筑可调节负荷的体量小且不确定性大，需要通过负荷聚集满足准入条件。其次，建筑用户在电力交易方面的专业能力不足，需要中介为其提供能力评估、接入方案、改造建议、调控策略等专业性的咨询服务和技术支持。中介与电力用户之间可以签署简单的零售合同，使建筑用户不用直接面对各

类复杂的电力市场交易规则。

- **用虚拟电厂实现灵活资源聚合。**虚拟电厂是一种能源电力的创新商业模式，可以实现分布式发电、储能和可调节负荷等电力灵活资源的聚合与调度，为了电网调峰开辟了新途径。从国家相关主管部门到电网企业，均出台了一系列政策、实施细则等予以支持，以鼓励虚拟电厂模式的探索与发展。在国外，虚拟电厂已经是一种成熟的商业模式；在国内，虚拟电厂才刚刚起步，相关的政策机制还不完善，主要是以试点示范的形式在推广。国内试点遍布上海、冀北、广东、山东等地，主要由电力调度机构发布邀约型需求响应，由城市工商业建筑负荷、居民建筑负荷和充电场站提供调节能力。
- **基于建筑柔性负荷的虚拟电厂。**在建筑柔性负荷参与电力调节的模式中，电网调度时需求的发出方，柔性建筑是灵活资源的提供方，虚拟电厂介于二者中间。虚拟电厂首先挖掘建筑的柔性负荷接入到聚合平台中作为资源池，然后根据电网调度的需求选择合适的资源进行协调控制，最后获得收益并与用户分享。基于建筑柔性负荷的虚拟电厂是一种新的业态，会带动一系列的支撑技术的发展，包括负荷柔性改造技术，建设能量管理技术、负荷聚集技术等。
- **建筑柔性负荷参与电力调节的优势。**第一，建筑柔性负荷体量大。建筑用电量占全社会四分之一，峰值负荷占比更高，如果能够把建筑负荷都聚集起来，调节潜力是巨大的。第二，建筑柔性负荷成本低。建筑用电设备已经安装，实现建筑用电设备负荷调节只需要增加能量管理系统解决通讯和协调控制问题。第三，建筑配套设施完善。建筑结构、配电设施、交通设施、物业运维体系也已经落成，未来在建筑中建设分布式储能设备，其施工成本、并网成本、运输成本、管理成本都比在城市中规划建设调峰电站和储能电站更具优势。
- **建筑柔性负荷参与电力市场的问题。**第一，建筑负荷主要适合解决日内的调峰问题，建筑负荷基本没有跨周的和季节性的储能能力。第二，建筑负荷的调节能力和调节成本不清晰。建筑设备种类繁多、运行规律多样、人行为复杂。建筑用户和负荷聚集商对建筑柔性负荷的调节能力和

调节成本缺少定量评价，导致建筑柔性负荷参与电力调节的经济性无法判断。第三，用户对新技术不理解。建筑是按照为人服务的原则设计的，没有人想到建筑负荷未来还要服务于电力系统调节。由于缺乏技术示范和经验积累，用户对于柔性用电技术不了解，对“源随荷动”到“荷随源动”的模式转变有担忧，影响了用户的参与意愿。

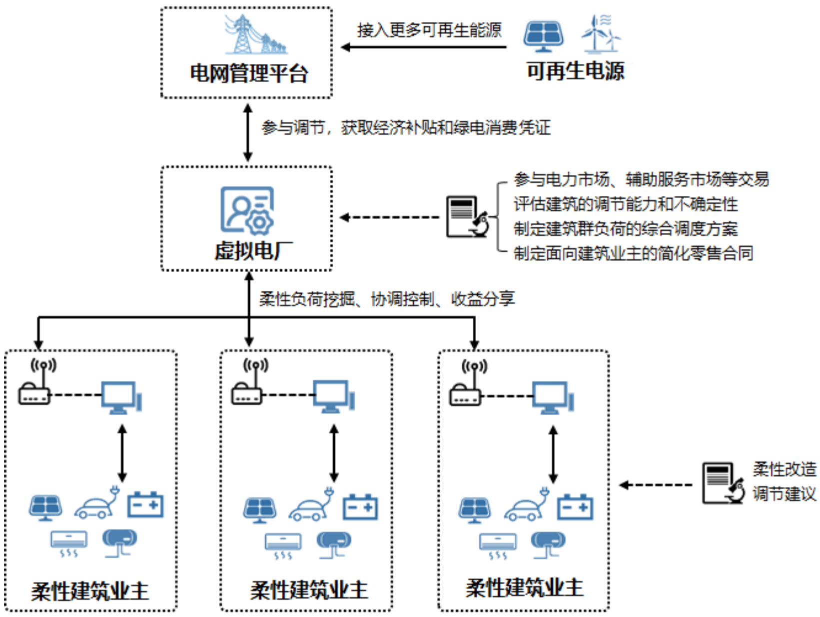

图 II 建筑负荷聚合参与电网调节的虚拟电厂模式

■ 虚拟电厂脱“虚”向“实”

- **调节能力定量化。**建筑负荷调节能力需要从多维度进行评价，包括调节容量、启动时间、调节速度、调节精度、持续时间等指标。不同用电设备有不同的调节能力，可以提供不同的调节服务。相应的，电力系统也会根据不同类型的调节需求提出调节能力要求，例如需求响应一般对调节容量和持续时间有要求、对功率偏差有考核，辅助服务对调节精度、响应时间、调节速度有较高要求。只有掌握了建筑负荷的调节能力，虚拟电厂才能为电网调节需求匹配合适的灵活资源，才能为用户制定更优的聚合调控方案。本项目通过实验测试，给出了主要建筑负荷调节能力的调节能力，并且基于建筑用电负荷曲线和电网负荷曲线设计调峰方案并且评估调峰效果。在现状情景，只有空调负荷和其他负荷参与电网调峰，电网峰谷差减少幅度 18%。未来，增加了储能和充电桩，在光电大

发情景和风电大发情景下电网峰谷差分别减少幅度 62%和 85%。

- **调节成本明朗化。**建筑负荷调节成本需要考虑建设成本、运行成本和聚合成本。建设成本是针对专门为柔性调节而增加的设备投资和功能投资，包括储能设施投资和实现充电桩放电功能的额外投资等；运行成本是指负荷调节造成的损失，包括对室内舒适度的影响、对生产生活效率的影响、储能充放过程的能量损耗等；聚合成本是指实现负荷调控的通讯成本和虚拟电厂平台开发成本等。只有掌握了建筑负荷的调节成本信息，建筑用户才能决策是否参与，虚拟电厂才能以经济性为目标进行资源优化整合。然而，建筑负荷调节成本的评估面临样本数据严重缺失的问题，无论是电网还是建筑用户都对负荷调节成本都没有概念，尤其在跟舒适度和生产生活效率关联的运行成本方面。
- **负荷聚集初见规模。**柔性用电、负荷聚集在建筑领域都是新概念。从设计、建造到运行，建筑都是服务于人的，没有人想到建筑负荷未来还要服务于电力系统调节，导致对建筑负荷调节能力和调节成本没有清晰的认识，对虚拟电厂模式用于聚合建筑负荷的可行性缺乏实践验证。在目前条件下全面推广也许面临较大障碍，建议先从示范工程做起，先把 100 万平米的建筑负荷聚集起来，把调节能力和调节成本研究清楚，把虚拟电厂模式、聚合算法、交易模式优化验证，进而为将来全面推广积累经验、奠定基础。

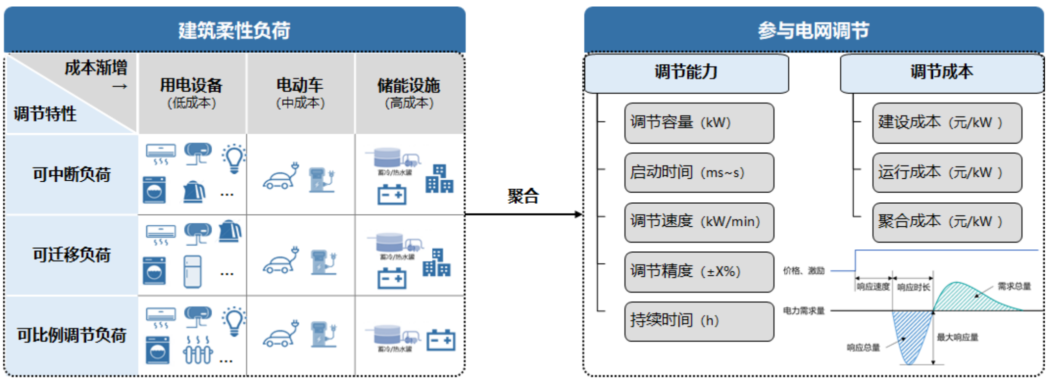

图 III 建筑柔性负荷的调节能力和调节成本

■ 绿电消费认证先立后破

- **建筑负荷调节行为的绿色贡献得不到充分体现。**绿色电力证书、绿电消费凭证、建筑电力碳排放量都无法充分体现建筑负荷调节行为的绿电消

费贡献，阻碍了柔性用电技术的应用和推广。可再生能源电力交易和电力市场、辅助服务、需求响应是完全不同的电力交易品种，在不同的平台上按不同的规则独立地进行交易，建筑用户很难意识到它们之间的关联性。建筑用户在寻找脱碳路径的时候，只能关注到与绿证直接挂钩的绿电交易这一个环节，尤其在目前还需要为绿色属性溢价购买的背景下，形成为绿电消费就是多花钱买证的理解。为了让用户对绿电消费有更清晰的认识，为了方便用户参与到绿电消费的行动中，也为了推动柔性用电技术的落地发展，需要制定基于柔性调节效果的绿电消费认证机制，对建筑负荷调节的绿电消费贡献进行认证，对建筑负荷调节的建筑碳减排价值进行评估。

- **短期靠绿电消费认证，带帽摸家底。**在负荷调节市场没有形成或逐渐形成的过程中，采用“给帽子”的方式具备一定的可行性。从未来高比例可再生电力的需求出发，建立建筑负荷调节能力的测评体系，当建筑具备经验证的调节能力后，电网相关部门做能力认证，允许该建筑接入电网管理平台接收调度计划。建立建筑负荷调节行为的绿电消费认证方法，当建筑按照调度计划运行并经考核合格后，电网为其发放绿电消费凭证。建设领域的认证机构采信电力系统的能力认证和绿电消费凭证开展零碳建筑认证。绿电消费认证方法可以是基于电力调度数据计算的分时碳排放因子，也可以是保障性消纳绿电量在电网内部的分配机制。对于建筑业主而言，在短期没有经济效益的时候，通过零碳建筑的帽子，能够使建筑负荷调节迈出第一步，助力负荷调节市场的形成；对于电力系统而言，摸清建筑负荷调节能力，可为下一步电力市场和辅助服务市场的机制调整积累数据。
- **长期看电力市场和碳市场，利益再分配。**随着越来越多的可再生电力接入电网，负荷灵活调节的价值逐渐显现；与此同时，“帽子”的宣传价值也随着技术示范推广而减弱。长期看，负荷调节市场需要通过电力市场、辅助服务市场、碳市场等激活。负荷调节行为对电力系统安全稳定运行的支持作用可以通过电力市场和辅助服务市场获得收益，对绿电的消纳作用可以帮助用户完成减碳指标，超额完成指标甚至可以通过碳市场出

售获得收益。

图 IV 柔性用电激励机制的实施路径

Executive Summary

How do buildings and power grids cooperate to achieve low-carbon development?

- **Buildings need to further reduce carbon emissions on the basis of energy conservation.** The construction field is changing from combined control of energy supply and energy consumption to combined control of total carbon emissions and emission intensity, and low-carbon development has become a new development direction. Electricity is the main form of building energy consumption, and it accounts for nearly 50% of energy consumption by building terminals. In order to achieve low-carbon operations of buildings, it is necessary to increase the proportion of green electricity consumption and reduce carbon emissions of building electricity. However, the characteristics of high floor area ratio and high load density of cities determine that the renewable energy around urban buildings is limited. In addition, energy demand growth caused by the rapid development of urban economy makes it impossible for buildings in most cities to achieve carbon balance by relying on energy conservation and rooftop photovoltaics (PV). On the basis of energy conservation, how to further reduce carbon emissions in buildings is a problem faced by urban low-carbon development.
- **Under the trend of wind power and PV integration, the demand for power grid peak regulation is ever increasing.** Currently, power grids are challenged by load peak of 100 hours. In the summer of 2021, many cities all over China suffered continuous high temperature, leading to sharp increase in the demand for air conditioners. During industrial production after recovery of the epidemic, the electricity load in many cities reached historical peak. Insufficient power supply occurred in many regions and the balance of supply and demand can only be achieved by orderly electricity consumption. Many cities took extreme measures of power rationing from time to time, which causes difficulties in industrial production and livelihood of residents. In the future, the demand for power grid peak regulation will further increase. With the increase in the scale of wind power, PV, and electricity integration, power shortage and power surplus occur repeatedly on a daily basis or even a shorter cycle. The peak regulation demand of the power system is no longer limited to load peak of 100 hours, but may be randomly distributed over 8760 hours throughout the year. The power system needs a large number of peak regulation and energy storage facilities, which can fill in the power gap in case of small wind power and PV and store excess power in case of large wind power and PV. Growing demand for power grid peak regulation creates opportunities for flexible resource development.
- **Flexible electricity consumption becomes a breakthrough point for buildings and power grids to join hands for low-carbon development.** From the perspective of the building, if the building energy system is optimized within the red lines, it is difficult to achieve the goal of carbon neutrality with limited resources and high energy storage costs. By connecting rich zero-carbon power resources through power grids to obtain more reliable power supply guarantees, the construction field can realize carbon reduction with lower costs. From the perspective of the power grid, adjustable loads such as air conditioners, water heaters, and charging piles in buildings are flexible resources with great potential. Exploiting flexible resources in buildings can help solve the growing demand for peak regulation and promote the development of variable renewable power sources such as wind power and PV. With flexible electricity consumption, buildings provide a large number of low-cost adjustable resources for power grids to help power grids conduct peak regulation. Accordingly, power grids provide buildings with a higher proportion of green power to help the buildings achieve electrification and low carbonization. Using flexible electricity consumption as a breakthrough point, buildings and power grids can work together to achieve low-carbon development.
- **Ideas of building energy conservation change to improvement in both energy efficiency and flexibility.** The model of low carbon development achieved by joint work

of buildings and power grids based on flexible electricity consumption changes the traditional ideas of building energy conservation. In the past, building energy conservation focused on the reduction of total electricity consumption, without identifying the differences in electricity saving time periods. In the future, the electric power market and green electricity trading market will help people find the differences in the economic cost and proportion of green electricity of electricity consumption in different time periods. Different economic and carbon reduction benefits will be achieved if each kilowatt-hour of electricity is saved in different time periods. In areas where the electricity price during peak hours is more than four times that of valley hours, saving each kilowatt-hour of electricity during the peak hours will achieve more than four times the benefits of that during valley hours. Energy efficiency will no longer be the only indicator of energy saving, and adjusting ability will also be valued.

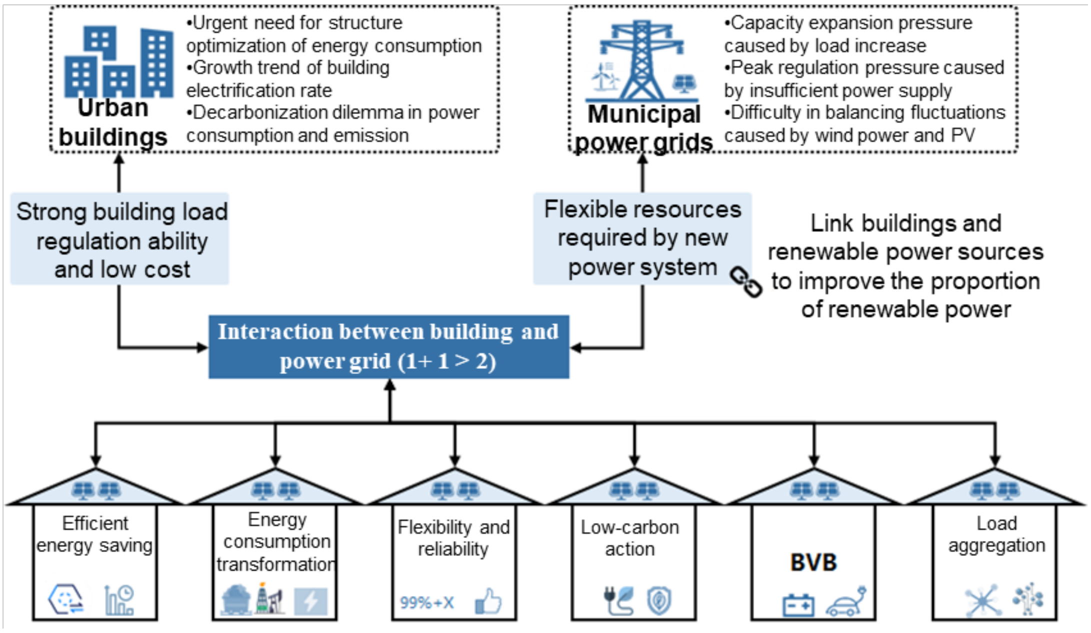

Figure I Low-carbon model achieved by joint work of buildings and power grids based on flexible electricity consumption

Virtual power plant (VPP) realizes flexible interaction between building and power grid.

- **Building load aggregation before exchanged with power grid:** First, due to management needs, various types of regulation products released by the power system, such as demand response (DR), interruptible load, primary frequency control, secondary frequency control, and peak regulation, have requirements on minimum capacity and regulation performance. Adjustable loads of the buildings feature small volume and large uncertainty, and they must be aggregated to be accessible. Second, building users do not possess sufficient professional skills in electricity trading, and agencies are required to provide them with professional consulting services and technical support such as ability assessment, access plans, reconstruction suggestions, and regulation policies. Agencies and power users can sign a simple retail contract, so that the building users do not have to directly deal with various complicated transaction rules in the power market.

- **VPP used to implement flexible resource aggregation:** VPP is an innovative business mode of energy power, which can realize flexible resource aggregation and dispatch of power resources, such as distributed power generation, energy storage, and adjustable loads, creating a new way for power grid peak regulation. A series of policies and implementation rules have been issued by relevant national supervision departments and power grid companies to encourage exploring and developing new VPP models. Outside China, VPP has become a mature business mode. In China, VPP is in the initial promotion stage, mainly in the form of pilot demonstrations, without complete policies and mechanisms. Pilot demonstrations of VPP are scattered in many cities and regions of

China, such as Shanghai, Guangdong, Shandong, and northern Hebei. Power dispatch agencies issue invitation-based DR, and the regulation ability is provided by aggregation of urban industrial and commercial building loads, residential building loads, and charging stations.

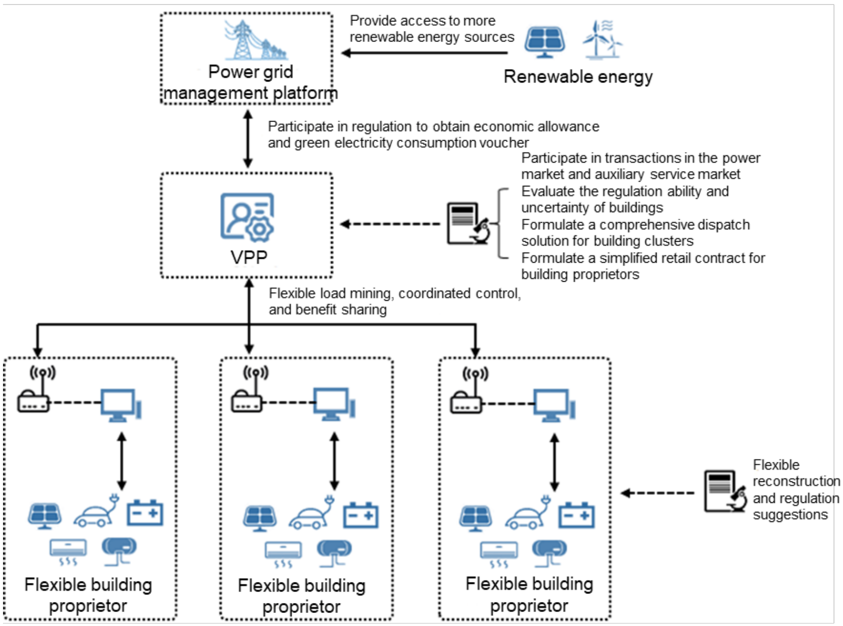

Figure II VPP mode allowing aggregated building loads to participate in power grid regulation

- **VPP based on flexible building loads:** When flexible building loads participate in power regulation, the power grid is the originator that issues a power dispatch demand, the flexible building provides flexible resources, and the VPP is located between them. The VPP mines the flexible building loads and connects them to the aggregation platform as a resource pool. Then, the VPP selects appropriate resources for coordinated control according to the dispatch demand of the power grid. Finally, the VPP shares the obtained benefits with users. VPP based on flexible building loads is a new business mode, which will drive the development of a series of supporting technologies, including load flexibility transformation, construction energy management, and load aggregation.

- **Advantages of power regulation with flexible building load engaged:** First, flexible building loads have a large volume. Building electricity consumption accounts for a quarter of electricity consumption of the whole society, with a higher proportion of peak loads. If the building loads can be aggregated, there will be huge regulation potential. Second, flexible building loads have low costs. The building electricity consumption devices have been installed, and an energy management system is required to enable communication and coordinated control during load regulation of these building electricity consumption devices. Third, buildings are equipped with comprehensive facilities. Building structure, power distribution facilities, transportation facilities, and property operation and maintenance systems have been implemented. In the future, deploying distributed energy storage devices in buildings will be more competitive than planning and building peak regulation power stations and energy storage power stations in cities, as far as the construction cost, grid integration cost, transportation cost, and management cost are concerned.

- **Problems of power market with flexible building load engaged:** First, building loads are mainly suitable for peak regulation on the day basis, and cannot be stored for regulation across weeks and seasons. Second, the regulation ability and cost of building loads are not clear. There are many types of building devices, diversified operating laws, and complex human behaviors. Building users and load aggregators lack quantitative evaluation on the regulation ability and cost of flexible building loads, so it is impossible to judge the economics of flexible building loads participating in power regulation. Third, users do not understand new technologies. Buildings are designed in accordance with the principle of serving people, but no one thinks that building loads can serve power system regulation in the future. Due to the lack of technical demonstration and experience accumulation, users have little knowledge of the flexible power consumption technology, and they are worried about the mode transition from "source following load" to "source followed by load", which lowers users' participation willingness.

VPP transits from virtual to reality.

- **Quantification of regulation ability:** The building load regulation ability should be evaluated from multiple dimensions, including regulation capacity, start time, regulation speed, regulation accuracy, and duration. Different electricity consumption devices have different regulation abilities and can provide different regulation services. Accordingly, the power system will put forward regulation ability requirements according to different types of regulation demands. For example, DR generally has requirements on regulation capacity and duration and assesses power deviation. Auxiliary services have relatively high requirements on regulation accuracy, response time, and regulation speed. A VPP can select appropriate flexible resources to meet power grid regulation demands and formulate better aggregation and regulation solutions for users only after it is capable of regulating building loads. This project tests the regulation ability of major building loads through experiment, designs a peak regulation solution based on the building electricity load curve and the power grid load curve, and evaluates the peak regulation effect. Currently, only air conditioners and other building loads participate in power grid peak regulation, and the peak-to-valley difference of the power grid is reduced by 18%. In the future, the peak-to-valley difference of the power grid will be reduced by 62% and 85% respectively for the large PV scenario and the large wind power scenario, when energy storage devices and charging piles also participate in peak regulation.
- **Explicit regulation costs:** Building load regulation costs should take the construction cost, operation cost, and aggregation cost into account. The construction cost refers to the device investment and function investment specially increased for flexible regulation, including the investment in energy storage facilities and the additional investment for the discharge function of charging piles. The operation cost refers to the loss caused by load regulation, including the impact on indoor degree of comfort, the impact on production and living efficiency, and energy loss in the process of charging and discharging of storage energy. The aggregation cost refers to the communication cost for load regulation and the development cost of the VPP platform. Only with regulation cost information of building loads, building users can decide whether to participate, and VPPs can carry out resource optimization and integration for higher economic goals. However, much sample data is lost for evaluating building load regulation costs, so neither power grid users nor building users have any idea of load regulation costs, especially the operation cost related to degree of comfort and production and living efficiency.
- **Load aggregation taking shape:** Flexible electricity consumption and load aggregation are new concepts in the construction field. The design, construction, and operation of buildings are to serve people, but no one thinks that building loads can serve power system regulation in the future. As a result, users do not have a clear understanding of the building load regulation ability and regulation costs and there is no practical verification on the feasibility of using the VPP mode on building load aggregation. Under the current conditions, there may be great obstacles to promotion in a wide range, so demonstration projects are recommended. The first step is to aggregate building loads of 1 million square meters and study the regulation ability and costs. The second step is to verify and optimize the VPP model, aggregation algorithms, and transaction model. Experience accumulated in these steps can lay a foundation for promotion in a wide range in the future.

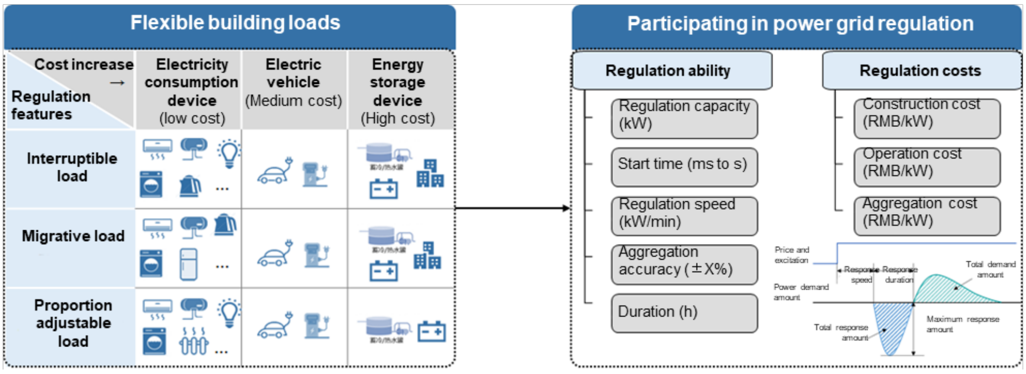

Figure III Regulation ability and costs of flexible building loads

Green electricity consumption certification, first stand and then break

- **The green contribution of building load regulation is not fully reflected.** Green power certificate, green electricity consumption voucher, and building power carbon emission cannot fully reflect the green electricity consumption contribution of building load regulation, hindering the application and promotion of flexible electricity consumption technologies. Renewable energy and power transaction is a power transaction type completely different from power market, auxiliary service, and DR. They are traded on different platforms according to different rules, so it is difficult for building users to realize the correlation among them. When seeking for a decarbonization path, building users only focus on the green electricity transaction that is directly linked to the green power certificate. Especially when green properties require a higher price, building users consider green electricity consumption as spending more money in buying certificates. In order to let building users have a clearer understanding of green electricity consumption, attract more building users to participate in green electricity consumption, and promote the implementation and development of flexible electricity consumption technology, it is necessary to set up a green electricity consumption certification mechanism based on flexible regulation effects. This mechanism is used to authenticate the green electricity consumption contribution of building load regulation and evaluate the carbon emission reduction values of building load regulation.

- **Rely on green electricity consumption certification and situation investigation in the short term.** Before the load regulation market is established or during the establishment process, it is feasible to adopt the method of certification. Establish an evaluation system for the building load regulation ability based on the demand for highly proportional renewable power sources in the future. When a building possesses the verified regulation ability, the relevant power grid department authenticates its ability and allows the building to access the power grid management platform to accept dispatch plans. Establish a green electricity consumption certification method for building load regulation. When the building operates according to the dispatch plan and passes the assessment, the power grid issues a green electricity consumption certificate to the building. The certification organization in the construction field adopts ability certification of the power system and the green electricity consumption certificate to carry out zero-carbon building certification. The green electricity consumption certification method can calculate time-based carbon emission factors based on the power dispatch data, or the method can also be used to distribute the guaranteed green electricity consumption within the power grid. For building proprietors, when there is no economic benefit in the short term, certificating zero-carbon buildings takes the first step to building load regulation and helps the formation of the load regulation market. For the power system, investigating the building load regulation ability helps accumulate data for mechanism adjustment of the power market and auxiliary service market in the next step.

- **In the long term, benefits will be redistributed to the power market and carbon market.** As more and more renewable power resources are connected to the power grid, the value of flexible load regulation gradually reveals. At the same time, the propaganda value of certified buildings decreases with technology demonstration and promotion. In the long term, the load regulation market should be activated through the power market, auxiliary service market, and carbon market. Load regulation supports safe and stable operations of the power system and can obtain benefits from the power market and the auxiliary service market. Load regulation accelerates green electricity consumption to help users complete the carbon reduction targets. Saved energy beyond the targets can be sold in the carbon market to obtain more benefits.

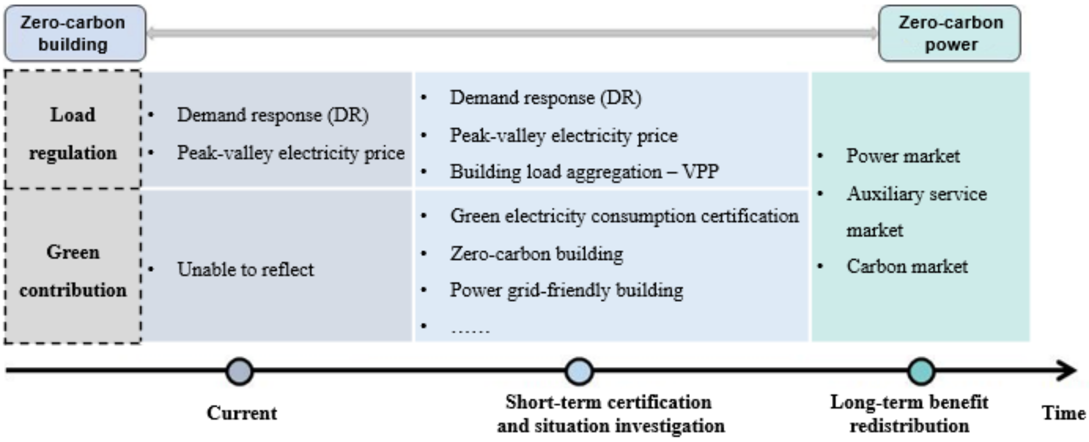

Figure 4 Implementation path of flexible electricity consumption excitation mechanism

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