DISRUPTIVE TECHNOLOGIES TO DECARBONIZE BUILDING ENERGY SYSTEMS

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Motivation

Buildings account for about 40 % of the final energy demand in industrialized countries and the operation of buildings contributes about 30 % to CO2 emissions. The EU and the German government aim at achieving an almost climate neutral building sector by 2050 [1]. To substantially reduce greenhouse gas emissions, a massive reduction of specific energy consumption rates of the building stock is necessary.

Technology and business model innovations as well as social factors and trends will have great impact on our energy supply. Will there be sufficient innovation and social changes to achieve the climate goals? Which disruptive innovations including technologies and business models as well as regulatory measures could speed up the transition? By applying theories of disruptive innovation (cp. Figure 1) and sociotechnical transition, this paper aims to characterize, identify, and qualitatively assess potentially disruptive technologies in the building energy context which are particularly promising for 2050.

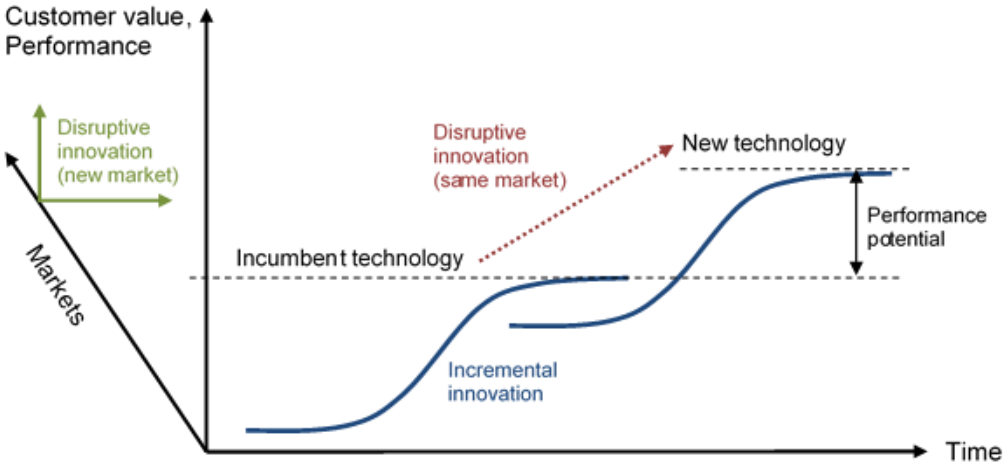

Figure 1: Extended S-curve model distinguishing incremental and types of disruptive innovation adapted from Fuchs and Golenhofen [2]

Methodology

This paper reviews several theories on innovation, disruption and disruptive technologies, which mainly originate from Bower and Christensen [3], as well as theories on sociotechnical transition [4]. A terminology is suggested, which is suitable for application to the building energy context.

Exemplarily, the historic shift from gas lighting to electric lighting and the application of photovoltaics in buildings are discussed in the frame of the theories on disruption and sociotechnical transition. Current megatrends influencing building energy systems (BES) are named. The involved stakeholders are identified as well as their corresponding interests and the performance parameters that are valued by them. Main causalities are identified between current trends, stakeholders, performance parameters and energy technologies that might foster disruptive change in BES.

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Emerging technologies were identified as potentially disruptive, following the steps below:

1) Criteria for disruptive technologies were applied to a variety of emerging technologies, considering current megatrends and the meeting of key performance requirements of stakeholders.
2) Potential impacts on BES and potential contribution for achieving the climate goals for 2050 were qualitatively assessed.
3) Potential improvements in customer value and increases in market shares were analyzed.

Results

Based on literature and analysis of historical examples, key criteria for potentially disruptive technologies are postulated: They need to meet current customer requirements that have been neglected by incumbent technologies and/or they have the potential to significantly increase customer value under current regulatory and market conditions.

Relevant current megatrends influencing BES are amongst else the digital revolution, decarbonization, customization, urbanization, demographic change, resource scarcity and participation.

The main stakeholders include building owners and users, energy suppliers, policy makers, entrepreneurs, engineers, craftsmen, and the public. The main performance parameters in BES are the meeting of comfort requirements within the building, economic performance, security of energy supply, low CO2 emissions and safety.

According to the above-mentioned criteria, three emerging technology groups have been identified as potentially disruptive for BES:

- flexible electricity-to-heat conversion devices, specifically heat pumps,
- electricity storage technologies, e.g. high-temperature thermal storages and batteries, and
- additive manufacturing of building parts or BES components.

The requirement of a large share of renewable energies (RE) in buildings is a scenario that severely impacts most stakeholders and makes key enabling technologies potentially disruptive. Heat pumps (HP) offer the potential to strongly increase the share of RE in the heating sector by coupling it to the electricity grid. Their market shares are increasing and HPs are already the leading heating technology in new buildings in Germany. Electricity storage solutions offer flexibility and could highly benefit from the economies of scale, which leads to rapidly decreasing costs and increasing installed capacity.

A main restraint in the building sector is the high individuality of buildings and their heat supply systems, which makes automated and serial production solutions difficult to implement. Manufacturing technologies that enable a high degree of customization, as e.g. additive manufacturing (AM), are therefore particularly promising. They act as catalysts for retrofitting existing buildings and can alter the development process due to rapid implementation. This impacts the value chain of new and refurbished buildings severely. Additionally, AM enables new forms of innovative and integrated design by which technologies may pass critical thresholds in customer value to enter new markets.

The paper concludes that the identified technology groups, which are particularly promising in combination with digital technologies and algorithms, will most likely reshape BES and will have a drastic impact on stakeholders and the technological building stock until 2050.

References

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