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Perspectives

Disruptive low-carbon innovations

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ABSTRACT

This perspective article considers the potential for disruptive innovations to transform the market for energy-related goods and services in line with emission reductions required for stringent mitigation. Its rationale is that consumers are a neglected constituency in societal efforts to meet climate policy objectives. First, I review Christensen's canonical definition of disruptive innovation as low-end products offering novel sources of value to users marginalised or over-supplied by mainstream markets. Second, I apply disruptive innovation concepts to the challenge of climate change mitigation and the necessary contribution of low-carbon innovation. There are both potentials for disruptive low-carbon innovations but also problems in achieving social benefits through the consumption of private goods. Third, I set out a series of criteria for disruptive low-carbon innovations and apply these to identify sets of potential innovations relating to mobility, buildings & cities, food, and energy supply. A wide range of consumer-facing innovations offer goods or services with novel attributes currently valued only in small market niches. Fourth, I report on the findings of two workshops on disruptive low-carbon innovation involving innovators, market intermediaries, policymakers and researchers. Different stakeholders hold sharply contrasting understandings of disruptive low-carbon innovation and its distinctive relevance for energy transformation.

1. Disruptive innovation

Personal computing is pervasive. But when first introduced in the late 1970s, the microcomputer performed poorly on all the attributes valued in the mainstream market for computers. The mainstream meant mainframes. Large firms and institutions demanded computers with ever-greater processing speed, storage capacity, reliability, and ever-lower costs per unit of information. Suppliers like IBM competed to service this demand. Relative to mainframes, the newly launched microcomputers were slow, limited, and unreliable. They appeared to offer no competitive threat. But they did offer something wholly new: portability (small volume, lower weight), versatility (ruggedness), low power consumption, and crucially, low unit cost. This value proposition was of no interest to mainstream market demand; but it did entice individuals and small firms as an entirely new segment of users. The rest is history. Steve Jobs and Bill Gates became household names and personal computers permeate daily life.

The microcomputer is used as a classic example of a 'disruptive innovation' by Clayton Christensen in his seminal book, 'The Innovator's Dilemma' [1]. Ranked by The Economist as one of the top six best business books ever [2], the Innovator's Dilemma has spawned a mini-industry in management scholarship and practice. Its central argument was that incumbents fail to see disruptive threats from innovations which offer non-mainstream users something wholly new. If successful, disruptive innovations effectively create a new market, a new set of demands and preferences. As a result their transformative potential is huge.

Christensen develops his argument by drawing on a range of innovations that disrupted mainstream goods and services provided by incumbent firms. Examples include: the microcomputer vs. the mainframe; desktop photocopiers vs. giant Xerox copy machines; digital photography vs. film; mobile telephones vs. landline services; small off-road motorcycles (e.g., Honda) vs. large powerful bikes (e.g., Harley); transistors vs. vacuum tubes; discount retailing vs. department stores; drones vs. bombers; Wikipedia vs. Encyclopaedia Britannica; massive open online courses (MOOCs) vs. university degrees; outpatient and in-home clinics vs. general hospitals [1,3–6]. In each case, the innovations enter the market as 'good enough' alternatives which enfranchise an under-served need or market segment [7].

The application and theorising of Christensen's arguments are principally concerned with firm strategy and performance. Disruptive innovations create asymmetric motivation as incumbent firms move up into higher-end, more profitable segments rather than counter the strategy of disruptive firms entering the market from below. Incumbent firms therefore ignore disruptive innovations and their niche users because of low returns and a lack of necessary internal processes, values or competencies.

But as the story of the microcomputer exemplifies, disruptive

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Nomenclature

Acronyms

DLCI	Disruptive low-carbon innovation
EV	Electric vehicle
ICE	Internal combustion engine
ICT	Information and communication technology
LED	Light-emitting diode
solar PV	Solar photovoltaic

innovations also have certain generic characteristics: they offer cheaper, simpler and more versatile alternatives to mainstream goods and services which have become over-specified in meeting many users' needs; they appeal initially to low-end, price-sensitive users or non-users; they underperform on attributes valued by mainstream users, but offer novel attributes or functionality to new users; and they develop in initial market niches until their performance on mainstream attributes improves or mainstream users' preferences shift towards the novel attributes offered (see Table 1).

Christensen also emphasises that the challenge with disruptive innovations is rarely technological but rather about finding a market. Early microcomputers largely used off-the-shelf components put together in a product architecture that was simpler than previous approaches. Incumbent manufacturers did just not anticipate new demand. Ken Olsen, the CEO of Digital Equipment Corp., one of the major players in the US computer industry, pronounced in 1977: "There is no need for any individual to have a computer in their home."

2. Disruptive low-carbon innovations

Low-carbon innovation is integral to research, policy and practice on energy transformation for climate change mitigation. Innovations from solar PV and offshore wind, to smart grids and large-scale storage, to electric vehicles and energy-efficient homes are strongly emphasised in modelling studies [10], mitigation scenarios [11], roadmaps & strategies [12,13], national climate plans [14], and R&D initiatives like Mission2020 [15]. The distinguishing feature of these low-carbon innovations is that they offer more efficient or lower carbon substitutes for the incumbent forms of energy production, distribution or use. Rather than improving functionality or offering novel attributes, low-carbon innovations provide the same basic service for end users. As a result they have limited consumer appeal.

Put differently, low-carbon innovations are overwhelmingly *sustaining*: they improve on existing product or service attributes [16]. This is dichotomous with *disruptive*: offering novel attributes and so creating a new value proposition. The distinction between sustaining and disruptive innovations (about attributes and users) contrasts with the widely-used typology distinguishing radical and incremental innovations (about technological improvements). Whereas *incremental* innovations improve cost or performance attributes without altering basic technological designs, *radical* or *breakthrough* innovations are discontinuously novel in their design architectures or fundamental technological concepts [17]. Using solar photovoltaics (PV) as an example, improvements in module efficiency may come from perovskite as a novel material concept (radical) or improved silicon etching techniques (incremental). But neither innovation is disruptive as – for the end user – solar PV continues to improve in cost and performance. In contrast, a business model innovation creating value from decentralised PV and battery storage with digitally-enabled peer-to-peer electricity trading is potentially disruptive as it offers end users new attributes of autonomy and independence (from grids and from utilities) and an active producer-trading role in electricity markets (in lieu of a passive consumer role).

Table 1
Characteristics of disruptive low-carbon innovations. (Note: ✓✓ = strongly concerned with; ✓ = concerned with; – = not concerned with).

	Christensen: disruptive innovation[a]	*Silicon Valley*: disruptive innovation[b]	*this perspective*: disruptive low-carbon innovation (Section 2)	*innovator workshop*: disruptive low-carbon innovation (Section 4)
novel application of knowledge (i.e., innovation)	✓	✓	✓	✓✓
initially attractive in a market niche then performance improves	✓✓	✓✓	✓	✓
disrupts mainstream firms, markets or regulatory frameworks	✓✓	✓✓	–	–
combines technological & business model innovation to create value	✓✓	✓✓	✓	✓
offers novel product or service attributes to users	✓	✓	✓✓	–
appeals to low-end market & price-sensitive users or non-users	✓✓	–	✓	–
simple, low-tech alternatives to over-performing mainstream goods	✓✓	–	✓	–
appeals to high-end market & price-insensitive technophile users	–	✓✓	✓	–
radical technological breakthroughs which improve exponentially	–	✓✓	✓	–
reduces greenhouse gas emissions if adopted at scale	–	–	✓✓	✓
requires supportive policy or regulatory environment	–	–	–	✓✓

[a] Source: Christensen [1], Govindarajan and Kopalle [3], and Lambert [6].
[b] Source: Seba [8] and Arbib and Seba [9].