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The Social Acceptance of Artificial Photosynthesis: Towards A Conceptual Framework

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Abstract: Advancements in artificial photosynthesis have the potential to radically transform how societies convert and utilize energy. Their successful development, however, hinges not only on technical breakthroughs but also acceptance and adoption by energy users. This article introduces a conceptual framework enabling analysts, planners, and even investors to determine environments where artificial photosynthesis may thrive, and those where it may struggle. The article proposes that social acceptance has multiple dimensions—socio-political, community, and market—that must be met holistically in order for investors and users to embrace new technologies. The article argues that any future market acceptance for artificial photosynthesis will depend upon the prevalence of nine factors, which create conducive environments; the lack of the conditions engenders environments where they will likely be rejected. The conditions are: (1) strong institutional capacity; (2) political commitment; (3) favorable legal and regulatory frameworks; (4) competitive installation and/or production costs; (5) mechanisms for information and feedback; (6) access to financing; (7) prolific community and/or individual ownership and use; (8) participatory project siting; and (9) recognition of externalities or positive public image.

Keywords: market acceptance; social acceptance; renewable energy
The Social Acceptance of Artificial Photosynthesis: Towards A Artificial Framework

1. Introduction

Scientific progress on artificial photosynthesis research has the potential to radically transform for the better how societies convert and utilize energy. One recent study proclaims that “no new technology has the long-term potential to so radically transform the planet towards sustainability as artificial photosynthesis engineered (alone or together with other technologies) in more efficient form as an ‘off-grid’ zero-carbon energy solution into all our structures (i.e., buildings, roads, vehicles).”¹ Another suggests that “global artificial photosynthesis could replace policy models of corporate globalization and ever-increasing economic growth predicated on preparation for war and use of non-renewable and polluting energy sources.”² Still another remark that if widely adopted artificial photosynthesis could enable humanity to transition from the “anthropocene,” our current geologic era, to a new, more sustainable and just one termed the “sustainocene.”³

These statements, while they underscore the promise of the technology, do not tell us how to get from now to then. Currently, the world receives far less than 1 percent of its commercial energy mix from sunlight, and transitioning away from fossil fuels requires that humanity counter the large sums of labor, capital, and effort historically “sunk” into conventional energy systems which enable them to have their own “path dependency” or “inertia.”⁴ Breaking out of these embedded systems requires a “long-term transformation”

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³ Thomas Faunce, Towards a global solar fuels project- Artificial photosynthesis and the transition from anthropocene to sustainocene, Procedia Engineering 49 (2012) 348 – 356.
that is “a messy, conflictual, and highly disjointed process.”

Collectively, these technological and behavioral forces “lock” us into a carbon dependent energy system that highly resists changes.

Thus this paper asks: what would need to happen, not in the technical dimension but the social dimension, to ensure that artificial photosynthesis becomes accepted? Put another way, what technical, social, economic, and political conditions promote the acceptance of new forms of clean electricity supply? To provide some answers, this article explores the factors influencing the acceptance of commercial-scale renewable electricity, drawn from historical examples in Asia, Europe, and North America. More specifically, the article argues that acceptance hinges upon the prevalence of nine factors: (1) strong institutional capacity; (2) political commitment; (3) favorable legal and regulatory frameworks; (4) competitive installation and/or production costs; (5) mechanisms for information and feedback; (6) access to financing; (7) prolific community and/or individual ownership and use; (8) participatory project siting; and (9) recognition of externalities or positive public image.

2. Conceptualizing the Social Acceptance of New Technologies

While the literature explaining or describing the market penetration of renewable resources is vast and growing, most of it has not been synthetic. Instead, some studies have investigated national styles of regulation, others have analyzed the barriers to specific types of renewable energy, and still others have analyzed what engenders social opposition to renewable energy, often through surveys of public attitudes and beliefs. Taking a step back

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10 Wolsink, M. Wind power and the NIMBY-myth: Institutional capacity and the limited
from this literature, and attempting to determine overall theories of acceptance, two recent studies have suggested that the acceptance of renewable energy has at least three dimensions: socio-political, community, and market.11 12

Socio-political acceptance is the broadest and the most general, and it concerns the ability for regulators, policymakers, and other key stakeholders to craft effective policies or frameworks that create and foster community and market acceptance below. This involves creating strong institutional capacity where countries exhibit institutional support at the national level through Ministries or Departments of Energy with specific programs or subsectors dedicated to solar energy and fuels, or have government sponsored institutes doing research. Political commitment is needed where political leaders make promoting renewable energy a highly visible topic. Favorable legal and regulatory frameworks must exist as well, so that laws and regulations facilitate ease of entry into solar market, independent renewable energy producers (even homeowners) are granted access to the electricity grid, national interconnection standards exist, and regulatory changes occur in a predictable and transparent manner.

Community acceptance is the most specific, and it involves the extent that projects are undertaken or invested in by local stakeholders, how costs and benefits are shared, and how policymaking is conducted. One key attribute is prolific community/individual ownership and use, where solar energy systems tend to be installed, owned, and/or or used locally. One is participatory project siting, where people and communities are involved in the decision to site or permit renewable energy facilities near them. One is recognition of externalities or positive public image. To meet this criterion, community members must be generally aware of the environmental impact of conventional energy and the benefits of renewables,

cultivating a strong public image. This is not to say that renewable energy must be perceived as having *no* negative externalities, only that it offers more net benefits than its alternatives.

Market acceptance operates at a meso level between national politics and local communities, involving consumers (that must adopt a technology) and investors (that want to support its manufacturing and use). This compasses market competitive installation/production costs where solar systems produce electricity at a competitive rate compared to other sources of supply, driven by government incentives, a large resource endowment, and/or a strong local manufacturing base. It depends on mechanisms for information and feedback, granting investors and users/producers access to reliable information about solar energy policies, prices, and opportunities. It envelops access to financing, where producers, manufacturers, and users have access to domestic sources of low cost financing and/or can benefit from specific government financing schemes.

Figure 1 shows how these three dimensions operate as a sort of nexus or triangle, implying that each form of acceptance is insufficient on its own to promote renewable energy; only environments where national social and political frameworks align with community interests and market drivers will see renewable energy rapidly adopted. It also implies that the broadest base of support must come from community members and end-users; that a smaller but still meaningful collection of investors and business leaders must lend their support; and that, at the top of the pyramid, a small but important group of policymakers and planners must give their endorsement.
Drawing from these attributes, we propose a conceptual framework consisting of nine factors to explain the acceptance of new electricity resources such as artificial photosynthesis, depicted in Figure 2. Table 1, drawing from an earlier study published by one of the authors, indicates how these nine factors were correlated with “successful” environments for other types of renewable energy—wind turbines and conventional solar photovoltaic panels—in Denmark, Germany, India, and the United States; the inverse were correlated with “failed” environments and low rates of adoption.
Table 1: Examples of Renewable Energy Acceptance in Germany, United States, Denmark and India (Modified from Sovacool and Ratan, 2011).

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Example(s)</th>
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<tbody>
<tr>
<td>Strong institutional capacity</td>
<td>India has a national Ministry of New and Renewable Energy</td>
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<td></td>
<td>The National Renewable Energy Laboratory in the United States and Risø National Laboratory in Denmark conduct research on various aspects of solar and wind energy</td>
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<tr>
<td>Political commitment</td>
<td>Parliamentarians Herman Scheer and Hans-Josef Fell staunchly support renewable energy as a way to revitalize the East German economy after unification</td>
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<td></td>
<td>Political parties in Denmark continually announce ever-more ambitious targets for wind energy in order to build a robust domestic manufacturing base</td>
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<td>Favorable legal and regulatory frameworks</td>
<td>Rules in Denmark force transmission system operators to connect all renewable electricity generators to the grid independent of its cost</td>
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<td></td>
<td>Changes to the German feed-in tariff scheme occur transparently every four to five years with input from a broad spectrum of stakeholders</td>
</tr>
<tr>
<td>Competitive installation/production costs</td>
<td>Germany rewards renewable energy producers with a premium tariff above the retail market price for electricity</td>
</tr>
<tr>
<td></td>
<td>Local production and manufacturing of wind turbines in Denmark lowers installation costs, enhances learning, and reduces risk</td>
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<tr>
<td>Mechanisms for information and feedback</td>
<td>Net metering in most states in the U.S. allow solar and small-scale wind producers to sell electricity back to the grid at real-time prices, making peak production more valuable</td>
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<td></td>
<td>Germany publishes information about policy mechanisms such as the feed-in tariff in newspapers and through free brochures</td>
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<td>Access to financing</td>
<td>Various banks and government programs offer preferential financing opportunities for residential solar systems</td>
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<td></td>
<td>The Danish government designed and promoted a “Danish Wind Turbine Guarantee” that offered financing for projects using Danish made materials and components</td>
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<tr>
<td>Prolific community/individual ownership and use</td>
<td>Ninety percent of commercial wind farms in Denmark are owned by local cooperatives and individuals</td>
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<tr>
<td></td>
<td>Roughly half a million families have installed solar panels on their homes in Germany</td>
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<tr>
<td>Participatory project siting</td>
<td>Trade unions, environmental groups, nongovernmental organizations, community leaders, and consumer advocates are all involved in German renewable energy permitting</td>
</tr>
<tr>
<td>Recognition of externalities or positive public image</td>
<td>Danish municipalities enthusiastically embraced wind energy as an environmentally friendly alternative to nuclear power</td>
</tr>
</tbody>
</table>
3. Conclusions and Implications for GAP

What does all of this mean for any project related to Global Artificial Photosynthesis, readers may rightly ask at this point? At least four things.

First, we subscribe to the notion that all energy technology (and indeed, all technology) is social and technical, or socio-technical. For any technology to be embraced, a “seamless web” of technical, political, economic, and social conditions must simultaneously and synergistically exist. This means that reliable technology is a precondition for all nine criteria, and is thus not placed in any of our three dimensions (although it is partially subsumed by competitive costs, since a poorly designed or unreliable technology would ostensibly cost more). It also means that all or most of our nine criteria are needed for acceptance to occur, in order for the “seamless web” to engender technology use.

Second, many of our criteria are interrelated, or at least have strong interactive effects between them. This is because we tried to be both mutually exclusive (each criterion is distinct from the others) with being collectively exhaustive (including a comprehensive list of metrics). In doing so, we have in essence blended together “producing” and “installing,” since “use” requires both to have happened. We have also blended together “individual” and “community” use together since these occur at a scale below the country or state/province.

Third, we treat acceptance as relative and different from diffusion. Our criteria and conditions are not believed to facilitate absolute acceptance, which would imply total market saturation, but an accelerated level of diffusion compared to other countries and places. Diffusion is a neutral term, in this case having large numbers of renewable energy systems

installed (and high installed capacity or production per capita). Acceptance is social, and refers to the diverse technical, social, political, and economic factors driving (or even constraining) diffusion. Acceptance of solar energy need not imply that such technologies are favored among producers and users; it could be that other energy options such as fossil fuels and nuclear power are disliked whereas stakeholders are apathetic towards renewable energy (i.e., it’s not that John Q. Public likes or even accepts solar energy, he just hates the thought of another coal plant, meaning solar “wins” by default). So it’s important to remember that acceptance for us is always situational and comparative.

Fourth, for the sake of simplicity we have treated each of our criteria as equal. It may be that some criteria are truly more meaningful and influential than others. Strong institutional frameworks and access to financing may be true “knockout” criteria that are always needed for acceptance whereas countries without consistent political commitment and participatory project siting may still create frameworks generally conducive to acceptance. Further research ought to perhaps “weigh” our criteria through conjoint choice analysis, clustering, or other techniques to create a hierarchy of importance.