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Introducing the Clean-Tech Adoption Model: A California Case Study

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Abstract. The Clean-Tech Adoption Model (C-TAM) explains the adoption process of clean technology. Based on the Unified Theory of Acceptance and Usage of Technology (UTAUT) combined with qualitative research and empirical data gathering, the model predicts adoption based on the perceived quality, effort, transition, experience and knowledge. Social media introduces a moderating effect, thus legitimizing its effectiveness as a marketing instrument on accelerating the adoption of clean technology. C-TAM is validated; however additional empirical research is necessary. Additionally, the explained variance discrepancy with UTAUT as well as theorizing on the Diffusion of Innovations theory stimulates further research on extra moderators.

Keywords: clean technology, adoption, C-TAM, social media marketing

1. Introduction

Clean technology has been a dominating subject on the global agenda. From politics to the business environment and from academic settings to innovative entrepreneurs, the environmental trend and innovative industry has created a big hype. Whether you are a clean-tech lobbyist or simply reject most claims made in name of environmental care and clean technology, nowadays most global residents accept its risk reducing character and innovative solutions as beneficial for mankind. Or, as Grimes states it in 2012 "The demand for renewable energy, the threat of global warming and climate change and the question of how to make the transition to an economy based on fossil-fuel alternatives are concerns for everyone". Despite its potential and 'semi-acceptance' of significance, the current (consumer) perception is fed by the thought that clean-tech was a promise that largely failed. While the year 2011 showed some major failures, including a few businesses that had received governmental funding, the clean technology industry is nevertheless growing rapidly and its overall acceptance and adoption is also growing. The fall of some companies is therefore primarily due to extreme competition rather than the intrinsic value of the products. And, although the exponential increase in companies investing in and developing clean technology made it almost impossible for all of them to survive (Pernick & Wilder, 2012), clean technology's future is still undeniable and therefore 'simply' needs a boost in marketing and sales (Simula, Lehtimäki & Salo, 2009; Hargadon & Kenney, 2011; Grimes, 2012). Though fast and successful are the technologies emerging, so slow and lagging are their adoption, implying that the focus should be on marketing and communications as well as product innovativeness, not solely on the latter. Based on this perception, this paper investigates the variables which determine the adoption of clean technology and presents a model to accelerate general clean-tech marketing. A definition is first provided since the clean technology terminology is somewhat ambiguous.

1.1. Clean technology definition

What is meant by clean-tech or clean technology? While there is no standard definition of "clean technology," it has been described by Clean Edge, a leading clean technology research firm, as "a diverse range of products, services, and processes that harness renewable materials and energy sources, dramatically reduce the use of natural resources, and cut or eliminate emissions and wastes." (Pernick & Wilder, 2007; Pernick & Wilder, 2012). According to Clift (1995) clean technology is a means of providing a human benefit which, overall, uses less resources and causes less environmental damage than alternative means with which it is economically competitive. More recently, other authors like Cooke (2008) and Grimes (2012) describe clean technology as the complex of industry activities dealing with energy-related agriculture, air and environment, materials, manufacturing, energy generation, efficiency, storage and infrastructure, recycling and waste treatment, transportation, water and wastewater that utilize renewable resources enhanced, as appropriate by life science technologies. This publication handles the Clean Edge definition. Because the term clean technology encompasses multiple types of technology, e.g. energy saving light bulbs,

specialized air-conditioning systems, or related sustainable building materials and electric cars, the scope of clean technology is delineated. Throughout this study, the term is qualified as 'new and innovative products of clean technology except for shopping goods'. That is, commodities that are not bought on a daily basis, but products that need consideration before buying, known as durable goods.

1.2. Marketing & Adoption

The global importance of clean technology is stipulated by many (Cooke, 2008; Hager, 2009; Veugelers, 2011; Almlund, Jespersen & Riis, 2012) as is its significance in reducing environmental risks (Clift, 1995; Pernick & Wilder, 2007; Roper, 2012). Still, the worldwide acceptance or even adoption of clean technology is only marginal at best (Pernick & Wilder, 2012). And even though (increasing) global care and (political) profiling, based on clean technology, have been predominant subjects on the agenda, and the acceptance gave rise to a substantial amount of innovative clean-tech producing companies (Pernick & Wilder, 2007; Pernick & Wilder 2012), the actual adoption does not parallel this exponential increase of product innovativeness. Exemplary, in 2011, Freed & Stevens stated that even today, as the $2.3 trillion global clean energy market emerges, American clean-tech entrepreneurs are at risk. Despite the judgement that the loss of venture capital in the United States will not derail technological innovation in clean technology worldwide, it could still severely set back and undermine American-owned clean technology innovation. As a consequence, if no action is taken and according to Freed & Stevens, economic growth will be greatly reduced. And to this matter the United States is no exception. In Europe for example, similar clean-tech companies are being perceived as being excellent at technology, but lacking in making business and creating export (Per, Claes, Gabriel & Claes, 2011). Authors Claes, Gabriel & Claes (2011) propose to invest now to ensure profits in the (near) future. The commercialization of new products has to be in such a way that revenue match development costs so as the venture become economically sustainably. Given this, global clean-tech companies demand a proven marketing strategy to convince, stimulate and direct consumers on adopting their clean technology products (Pernickes & Wilder, 2012). Given the fact that lacking widespread adoption can be fatal to the developing organization, product innovation in clean-tech should be equally paralleled by marketing and adoption within the segment. Hence, specialized marketing resulting in overall adoption is mandatory (Floor & Van Raaij, 2010). Hargadon & Kenney (2011) address to these issues by identifying several variables in clean-tech marketing. They state inter alia that the market must be large and rapidly growing and the solutions must be scalable. In 2012 they additionally claim that clean technology businesses can and should grow using self-financing (in contrast to the contemporary frequent subsidizing). Both approaches are closely intertwined with marketing and towards these characteristics marketing strategies are crucial (Roger, 1976; Rogers, 1995; Floor & Van Raaij, 2010). As underlined by Kemp & Volpi (2008), the overall conclusion is that the diffusion of clean technology, same as the diffusion of normal innovations, is governed by endogenous and exogenous mechanisms. However, before marketing can influence and persuade towards adoption, the variables determinative in this have to be identified. These insights and conclusions resulted in formulating the primary research question:

"What variables determine the adoption of clean technology?"

Within the marketing discipline social media are being perceived as effective instruments (Safko, 2010; Zarella, 2010; Packer, 2011). Whether used for electoral gain in politics (Riezebos et al., 2011) in healthcare promotion (Chou et al., 2009) or towards business practices in business (Smith & Zook, 2011), the significance of these multidisciplinary and multi applicable online tools is undeniable. Beside their proven effectiveness social media are both affordable and have a significant reach. Compared to the traditional media, social media have the potential to unleash an informational catalyst within (Safko, 2010). Considering these effects we are interested in the potential of social media in marketing clean technology, resulting in the secondary research question:

"Are social media effective in marketing clean technology?"

1.3. Research Purpose

This paper is part of the 'Raak' project in the Netherlands. The 'Raak' project is a multiannual Dutch trajectory between governmental organisations, the regional entrepreneurial environment and academic institutions. The project primarily focuses on strategic solutions for innovative entrepreneurs and organisations with an emphasis on technological innovation. A separate component of the 'Raak' project is the Raak International Clean Tech Community Project (RICTCP). The RICTCP has established a strong collaboration between the Eastern part of the Netherlands and Silicon Valley in the United States. This publication is part of the RICTCP in which the aim of the study was to identify the critical success factors as

part of the marketing strategy for clean-tech entrepreneurs and companies worldwide. In determining these factors a preference surfaced for psychological and financial barriers on adoption and investment.

2. Model & Hypotheses

2.1. Conceptual Model

The conceptual model was developed by means of a case study procedure. Alongside extensive literature research the Unified Theory of Acceptance and Use of Technology (UTAUT) from Venkatesch et al. (2003) was used in predicting the variables responsible for the adoption of clean technology. These informational resources functioned as guidelines for the then following semi-structured interviewing in the fall of 2011 and early 2012. Covering six weeks, 22 clean technology experts, consisting of academics, policy makers, politicians and business consultants, were consulted in California, United States. On location in San Francisco, Palo Alto, Davis and Berkeley, the experts participated in qualitative research by means of semi-structured interviewing. Throughout the duration of the interview the respondents reflected and discussed the variables which to their opinion influence the adoption process of clean technology.

After data collection the results were analysed using open coding. In order to prevent blindness and experimenter's bias a second independent analysis was performed. Cohen's Kappa inter-rater reliability analysis scored .9 and therefore clearly indicated homogeneity among both reviewers. The identified variables (codes) are quality, effort, transition, experience, knowledge, law regulations, financial incentives and social influence. Especially the importance of knowledge, ranging from informational to fundamental knowledge, is articulated as consequential. The experts postulated on the fact that overall, insufficient education on to topic clean technology is a permanent and restrictive phenomenon. In addition, all experts positively agreed on the questions concerning the suggested effectiveness of social media on clean-tech marketing. For this reason, in accordance with the second research question, the inclusion of social media as a separate influencer is justified (figure 1).

All independent variables are transformed into constructs (factors) and represented by 4 individual items within each construct. The dependent variables, 'Intention to use' and 'Adoption', are, in line with the UTAUT model, determined by 2 items. The construct 'Quality' refers to the perceived quality of the clean technology in comparison to the traditional technology. 'Effort' indicates the amount of perceived effort the adopter has to invest towards successfully using the technology. The construct 'Transition' reflects the overall adoption process were traditional technology is completely substituted by clean technology and 'Experience' takes into account the adopter's experience on the use of clean technology. 'Knowledge' is the adopter's knowledge and expertise on clean technology. 'Law' is the implemented and upcoming regulations, both national and federal, and their modulating effects on the use of clean technology. 'Financial' stipulates financial incentives which stimulate adoption, these can be both subsidies as well as financial reductions by the relevant company, and, finally, 'Social influence' are external influencers, i.e. the opinion of others and corporate or marketing communication. The type of social influence used is known as identification (Cialdini, 2001).

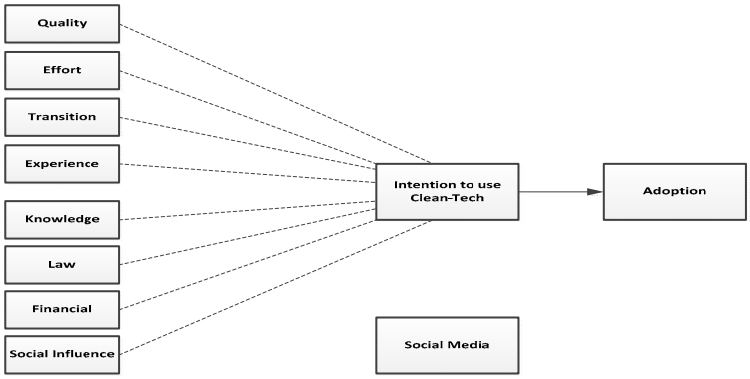

Fig. 1: C-TAM conceptual model

2.2. Hypotheses

Based on the conceptual model, as illustrated above in figure 1, the following hypotheses are formulated:

Hypothesis 1 "Intention to use is codetermined by the perceived quality of clean technology"

Hypothesis 2 "Intention to use is codetermined by the perceived effort on adopting clean technology"
Hypothesis 3 "Intention to use is codetermined by the transition from traditional towards clean technology"
Hypothesis 4 "Intention to use is codetermined by the perceived experience on clean technology"
Hypothesis 5 "Intention to use is codetermined by the perceived knowledge on clean technology"
Hypothesis 6 "Intention to use is codetermined by the law regulations"
Hypothesis 7 "Intention to use is codetermined by financial incentives"
Hypothesis 8 "Intention to use is codetermined by social influence"
Hypothesis 9 "Social media functions as a moderating variable on C-TAM"

3. Results

In 2012 empirical data collection was completed by means of an online questionnaire. Before distribution this quantitative instrument was pre-tested by four randomly assigned individuals. The outcome did not change the final version. Research awareness was accomplished by using online and social communication instruments (i.e. websites, newsletters and micro blogging). The participants in the qualitative method aided in promoting the study. Subsequently, to ensure an acceptable N, the top 100 Californian based clean technology companies were activated to enforce knowingness. After four weeks of consecutive measuring a total of 183 respondents participated in the study, of which 180 were usable (frequency analysis resulted in n=180).

3.1. Data Analysis

Data analysis was performed using SPSS 20.0. First, Cronbach's alpha was utilized to test construct reliability. The statistical procedure indicates strong reliability for each construct, as table 1 is showing, with each version consisting of two (dependent variables) or more items (independent variables).

Tab. 1: Construct Reliability

Construct	Alpha
Quality	.817
Effort	.893
Transition	.729
Social Influence	.650
Law	.882
Financial	.890
Knowledge	.747
Experience	.725
Social Media	.882
Intention	.948

Second, the Kaiser-Meyer-Olkin method (KMO) was used to determine the legitimacy of a factor analysis, in order to indicate possible data reduction. KMO measured .532 which is below the threshold level of .6, thus excluding factor analysis as a reliable procedure. Third, the overall correlations of the model variables were subjected to statistical analysis. Table 2 is indicating strong correlations among all included variables, with the majority at the <.001 p value level (2-tailed).

Tab.2: Correlation analysis

Construct	Effort	Transition	Social Influence	Law	Financial	Knowledge	Experience	Quality	Intention
Effort	1	.102	.461**	.381**	.397**	.686**	.350**	.673**	.353**
Transition	.102	1	128	.090	.444**	.104	.629**	.135	.274**
Social Influence	.461**	.128	1	.471**	.590**	.712**	.082	.311**	.174*
Law	.381**	.090	.471**	1	.401**	.664**	.357**	.181*	.032
Financial	.397**	.444**	.590**	.401**	1	.440**	.200**	.451**	.200**
Knowledge	.686**	.104	.712**	.664**	.440**	1	.327**	.630**	0.44
Experience	.350**	.629**	.082	.357**	.200**	.327**	1	.287**	.472**
Quality	.673**	.135	.311**	.181	.451**	.630**	.287**	1	.063
Intention	.353**	.274**	.174*	.032	.200**	.044	.472**	.063	1

**Correlation is significant at the 0.01 level (2-tailed)
* Correlation is significant at the 0.05 level (2-tailed)

Although correlation analysis strongly underlines the hypothesized relations, multiple regression analysis only detects significant relations on Quality, Experience, Effort, Knowledge and Transition. Still, the method does not suggest exclusion of the constructs Financial, Law as well as Social Influence. To determine if these should be excluded from C-TAM a stepwise multiple regression analysis was performed. This statistical procedure reduces the model to 5 independent variables, rejecting Financial, Law and Social Influence. However, due to the strong correlations in table 2, multi-colinearity, elements that correspond to one another and that are arranged in the same linear sequence, is expected to manifest itself within the model. Multi-colinearity analysis indicates colinearity among the factors Financial, Law, Social Influence and Knowledge. These effects are in line with the data reduction suggestion from both the regular and stepwise multiple regression analysis as well as the factor analysis. Despite the fact that the latter was disqualified based on the low KMO score, the outcome of the factor analysis also aimed at this data reduction. Because the merge of Financial, Law and Social Influence with Knowledge is suggested by several statistical methods they are combined into a single construct named Knowledge. This new construct is now explained in respect to overall knowledge including knowledge of financial incentives, on legal regulations and by means of social influence, and excluding the experience, effort, quality perceptions and firstly identified knowledge construct.

Stepwise multiple regression analysis issues an R of .775, Adjusted R Square .589, and .011 significance. Furthermore, an ANOVA of F 52,268 with the p-value significant at the .000 level. This states that the suggested Clean-Tech Adoption Model claims 59% of the total variance in the adoption of clean technology (hypotheses 1, 2, 3, 4 and 5 are accepted, where the latter is being modified). The Stepwise multiple regression analysis suggests a new model, eliminating the constructs Law, Financial and Social Influence (hypotheses 6, 7 and 8 are rejected).

Tab. 3: Coefficients

Construct	Beta	Sig.
Experience	.757	.000
Effort	.874	.000
Knowledge	.195	.006
Quality	.207	.003
Transition	.162	.011

Based on the results the conceptual model has been modified, as illustrated in figure 2. As indicated in table 3, the determining impact of the amount of experience and effort on clean technology is strong. Their Beta's account for both the highest impact as well as the strongest significance. Compared to the other factors the outcome of the data analysis suggest that possible adopters are especially interested in the amount of effort they have to invest in adopting clean technology. Interestingly, Knowledge, including financial incentives, scores distinctly lower. Based on these results and the clear data reduction we conclude that the extreme focus on financial incentives is less important than often assumed.

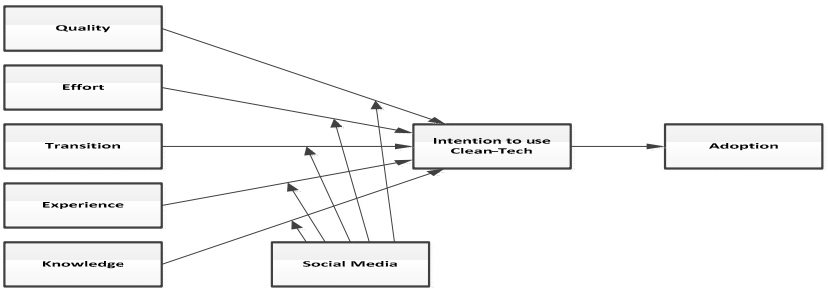

Fig. 2: Validated C-TAM model

Measurement of the interaction effect underlines the earlier assumption that social media could be used as a marketing instrument in accelerating the adoption of clean technology (hypotheses 9 is accepted). The moderating variable influences the relations among the independent variables and the dependent variable and shows its strongest effect on the relation of knowledge on the intention to use. This indicates that overall knowledge, as well as knowledge on financial incentives and law regulations, could be intensified by means

of using social media marketing. Marketing managers are therefore suggested to focus their informational distribution on these online media. The current shortage of social media marketing is being perceived as a missed opportunity and the C-TAM model underlines this claim.

4. Discussion & Findings

Summarizing the above we conclude this paper by stating that the C-TAM, and its validated variables, is a useful model in predicting the adoption of clean technology. The 59% of explained variance is scientifically strong, and given all significant reliability results, correlations and coefficients we expect the robustness of the model to be continually validated by future (empirical) studies. Positive experiences and the amount of perceived effort to adopt clean technology are regarded as leading factors in the model. In contrast, perceived quality as well as the ease of the overall transition both account for a minor impact. Knowledge, now consisting of the overall understanding of clean technology combined with governmental regulations (financial and legal) and social influence also has a small, but still significant, effect.

Being uneducated and misinformed were two important conclusions the experts stated in the semi-structured interviewing. The empirical validation of C-TAM indicates that being educated, represented by knowledge and general perception, is a significant and determining factor in the adoption process of clean technology. Hence, this influencer is an even stronger regulator than 'regular' financial and legal incentives. The study therefore suggests more marketing activities based on education of the possible adopters, for example through the use of social media, as these are identified as influential clean-tech marketing instruments (one can even go so far to state that part of public funding should be allocated for such mediated communication). Theorizing on the moderating influence of the construct social media, this new online and social instrumentation could well be used in optimizing knowledge. Thus, implementing social media in marketing strategies could be very beneficial in educating the target groups. On the educational needs and recommended use of social media, a focus on effort and transition is suggested. The results of the study indicate that increasing understanding could facilitate adoption. In addition experience should be stimulated by allowing possible adopters to experience clean technology themselves. Combined with gained knowledge and experience on clean technology, the adoption rate is expected to significantly advance. Regarding the adoption in general it is mandatory to focus on the perceptions of potential adopters. Besides knowledge and effort, adopter's self-efficacy and perceptions concerning overall transition towards using and, eventually, adopting clean technology, is crucial. Their current unawareness of clean technology's potential, its benefits and the governmental regulations hinder adoption.

Despite the predominantly positive findings, the scope of the study and its results are limitative. Multiple considerations should be taken into account. For example, the significance of underlying (moderating) variables beside the ones already identified. Theorizing on the Diffusion of Innovations theory by Rogers (1995), which stresses the importance of adopter types, learns that the adopter type could be an important (co-regulator) in C-TAM. Divided into five segments, the suggested adopter types all have 'different adoption moments' in which they appear fairly steady. Taking this into account the so called adopter types could very well be a second moderating effect. Furthermore, existing moderating effects of UTAUT, gender and age, were disregarded as moderating effects in C-TAM. Given the model's near 60% of total variance compared to UTAUT's 60% - 70% (Venkatesch et al. 2003; King & He, 2006) of overall variance, legitimizes their inclusion in a new study. Finally, the study used an n=180 to validate the model. Considering the amount of variables N is acceptable, however a larger empirical data set is required in fully validating C-TAM. Moreover, as the data gathering was exclusive to California, additional research is preferred for nationwide or even cross-cultural validation.

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