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研究課題名（和文）Social Energy System Design Incorporating AI and Lived Experience

研究課題名（英文）Social Energy System Design Incorporating AI and Lived Experience

研究代表者
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交付決定額（研究期間全体）：（直接経費）　　3,500,000円

研究成果の概要（和文）：本研究では人々の日常生活における行動や嗜好を考慮した環境、経済、社会的課題に関する重要性を予測するフレームワークを開発した。今までの研究では統計学を多く用いられたものが多く、等研究では機械学習の決定具分析を用い、より少ない情報にて予測能力を高める試みであった。フレームワークを活用し、少ない設問及び情報で重要な要素を可視化し、適切なエネルギーシステムデザイン及び政策提案ができた。研究成果として2編の論文が投稿され、2023年に一編が出版され、2編目が査読中である。

研究成果の学術的意義や社会的意義
The research is scientifically significant as it allows us to streamline the acquisition of data and it's application to machine learning to identify factors and preferences that were either unclear, or unable to be extracted from small data sets. Energy system design applications are also exciting.

研究成果の概要（英文）：This research seeks to understand how people’s daily behaviors and preferences may influence their perceived importance of environmental, economic and social issues. To date a lot of research has been grounded in survey and statistical analysis-based approaches. Here, we seek determine the efficacy of decision tree machine learning approaches which only employ non-identifiable data to estimate people’s perceived issue importance based predominantly on behavioral inputs. Machine learning approaches as proposed in our framework can make predictions as to whether certain issues are important to people based not only on demographics but also on a suite of daily behaviors. This framework may provide a streamlined policy instrument for policymakers to develop energy policies which align with people’s values and therefore may be more effective for energy system design. In this research project we submitted two journal articles, 1 published and 1 is under review.

研究分野：Energy Analysis

キーワード：energy system　preference　behavior　machine learning

１．研究開始当初の背景

The initial background of this research was the need to reduce survey fatigue, and to more accurately and efficiently apply lived experience factors to energy system preferences and the prediction of importance of energy system related factors.

Our current approaches to survey analysis involved the deployment of multiple questions which often meant that respondents would become fatigued and provide sub-optimal responses. The analysis would then focus on statistical approaches, which, in many cases could determine positive or negative associations. Machine learning on the other hand has the potential to derive predictions on a smaller subset of data, thus reducing survey fatigue and the cost of implementation.

２．研究の目的

The first goal of this research is to develop a machine learning framework to establish the veracity of our claim that the imposition on people and analysis methods can be reduced. The second, and main goal of this research was to establish a machine learning framework that not only can predict social, environmental and economic importance values, but can apply these to sustainable, desirable energy system design.

３．研究の方法

This research utilized 3 main methodologies. The first was the evaluation of previous surveys taken to date to establish statistical correlation and associations and to evaluate through the use of multiple machine learning models, the ability to predict specific energy system design related importance factors.

Based on the research outcomes of this body of work, a survey was designed, using multiple in person workshops, and deployed in Japan to clarify the role of machine learning (Decision Trees) in predicting the linkage between everyday and consumption behavior on environmental, social and economic importance.

Finally comparative analysis was undertaken on the ability of both statistical and machine learning approaches to predict linkages and significance, such that we can derive policy implications for sustainable, desirable energy system design.

４．研究成果

This research led to two publications, the first of which is referred to in the previous section, published in Energies in 2022 (Chapman, A. Enhancing Survey Efficiency and Predictive Ability in Energy System Design through Machine Learning: A Workflow-Based Approach for Improved Outcomes. Energies 2023, 16, 4911. https://doi.org/10.3390/en16134911).

This research sought to test this hypothesis, utilizing multiple algorithms and survey datasets to elicit common factors which are influential toward energy system preferences and energy system design factors. Our research has identified that machine learning models can predict response ranges based on preferences, knowledge levels, behaviors, and demographics toward energy system design in terms of technology deployment and important socio-economic factors. By applying these findings to future energy survey research design, it is anticipated that the burdens associated with survey design and implementation, as well as the burdens on respondents, can be significantly reduced. The research flow is presented in Figure 1.

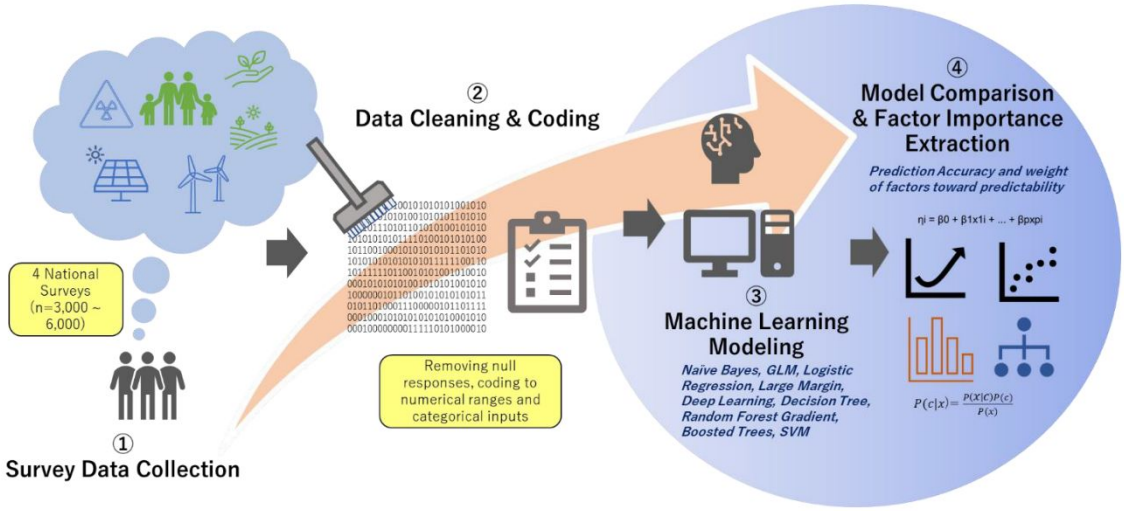
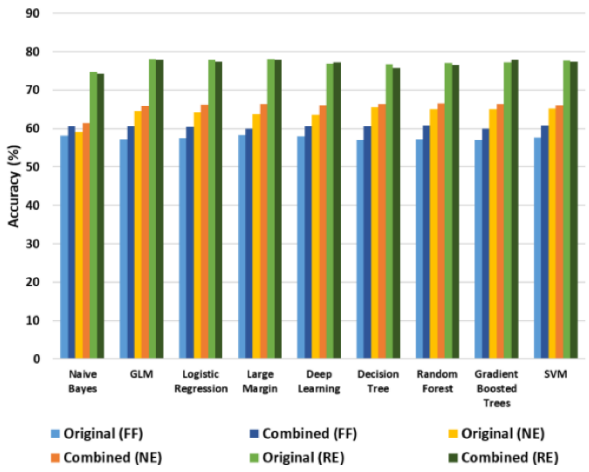
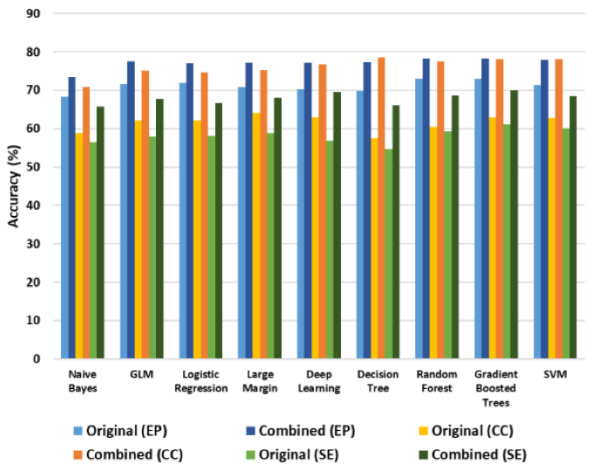


Figure 1. Research flow chart

Through the consideration of multiple machine learning models, it was shown that accuracy can be improved through the matching of modelling approaches to data sources, and that combining surveys (i.e., adding data) does not necessarily improve prediction accuracy (Figure 2).



(a)



(b)

Figure 2. Combined survey predictive performance change compared to single survey analysis for (a) energy system design and (b) energy system preferences

Building on this body of work, noting that decision trees have strong explanatory value for factor importance and seeking to contrast the merits of statistical analysis and machine learning, a survey of 4,00 people in Japan was deployed and analyzed with a new machine learning model. Results showed that statistical analysis can extract the critical demographics which influence perceived issue importance, as well as highlighting some behaviors which consistently influence these importance levels. On the other hand, a machine learning approach, rather than giving significance and strength of relationships, make predictions as to whether certain issues are important to people based not only on demographics but also on a suite of daily behaviors. This tool, which does away with the need for intrusive survey questions may provide a streamlined policy instrument for policymakers to develop energy policies which align with people's values and therefore may be more effective. Figure 3 describes prefectural levels of importance, while Figure 4 shows critical factors for the prediction of these values.

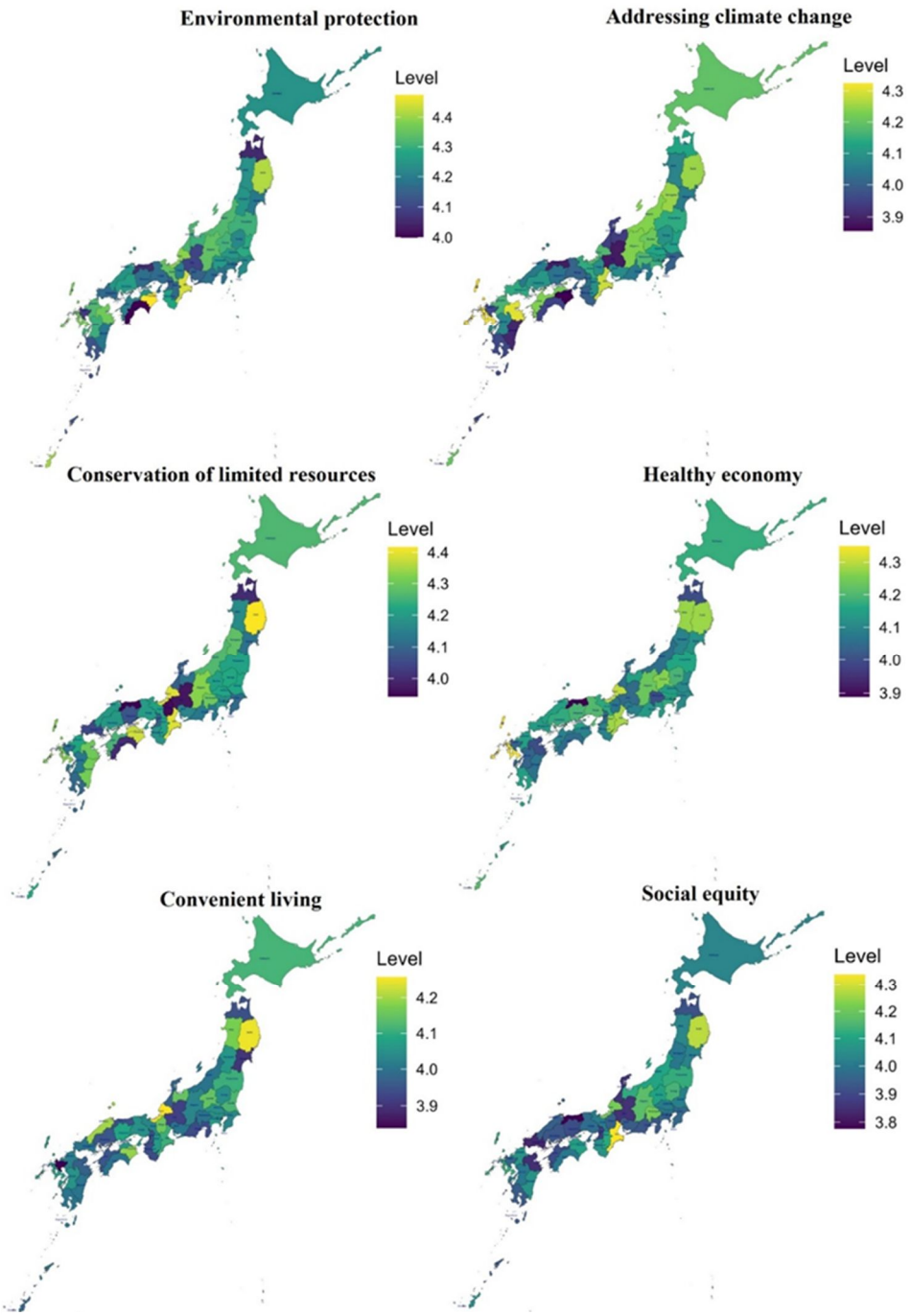


Figure 3. Average Issue Importance Levels Expressed by Prefecture

As can be seen in Figure 3, by issue, importance varies across Japanese prefectures and regions.

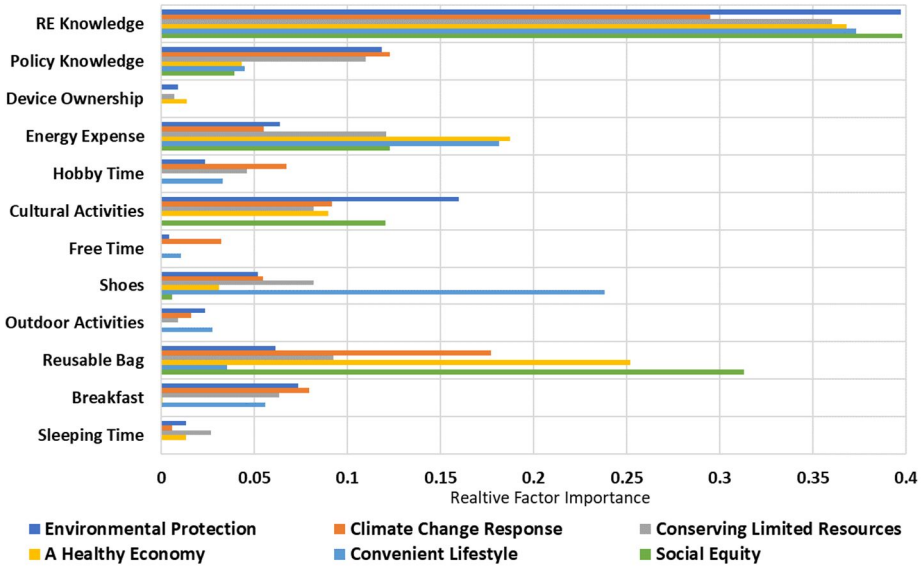


Figure 4. Model results

Of interest to us, as shown in Figure 4, is he relative strength of daily behaviors (shoe ownership, using eco-bags, undertaking cultural activities etc.) on predictability when compared with factors such as level of energy expense or technological and policy knowledge levels.

This research is currently under review in the Journal of Cleaner Production (Chapman, A. Mochida, T. Sen, K.K. Can personal preference and behaviors serve as proxies for energy and sustainability preferences? Contrasting statistical and machine learning approaches. Journal of Cleaner Production (Under Review)).

５．主な発表論文等

〔雑誌論文〕　計1件（うち査読付論文　1件／うち国際共著　0件／うちオープンアクセス　1件）

１．著者名 Chapman Andrew	４．巻 16
２．論文標題 Enhancing Survey Efficiency and Predictive Ability in Energy System Design through Machine Learning: A Workflow-Based Approach for Improved Outcomes	５．発行年 2023年
３．雑誌名 Energies	６．最初と最後の頁 4911～4911
掲載論文のDOI（デジタルオブジェクト識別子） 10.3390/en16134911	査読の有無 有
オープンアクセス オープンアクセスとしている（また、その予定である）	国際共著 －

〔学会発表〕　計4件（うち招待講演　3件／うち国際学会　1件）

１．発表者名 Andrew Chapman
２．発表標題 Achieving a Sustainable Transition: Energy System Design, Behavior and Innovation
３．学会等名 Mirai 2.0（招待講演）
４．発表年 2022年

１．発表者名 Andrew Chapman
２．発表標題 Holistic sustainability evaluation framework cognizant of demographics and behavior
３．学会等名 EcoBalance 2022（国際学会）
４．発表年 2022年

１．発表者名 Andrew Chapman
２．発表標題 Achieving a just transition: Energy system design and social equity
３．学会等名 Sustainable Economy Research Group（招待講演）
４．発表年 2022年

１．発表者名 Andrew Chapman
２．発表標題 機械学習を用いたエネルギーシステムデザインと レジリエンス
３．学会等名 九州脱炭素化研究会（招待講演）
４．発表年 2023年

〔図書〕　計0件

〔産業財産権〕

〔その他〕

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６．研究組織

	氏名 （ローマ字氏名） （研究者番号）	所属研究機関・部局・職 （機関番号）	備考

７．科研費を使用して開催した国際研究集会

〔国際研究集会〕　計0件

８．本研究に関連して実施した国際共同研究の実施状況

共同研究相手国	相手方研究機関