

Supplementary material

Application of technology assessments into co-learning for regional transformation: A case study on biomass energy systems in Tanegashima

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Biodiesel technology implemented in Tanegashima

Biodiesel is commonly derived from triacylglycerides (TAGs) in vegetable oils or animal fats with trans-esterification reaction, where TAG reacts with methanol to form fatty acid methyl esters (FAME), coproducing glycerol, which can be employed as a renewable fuel mitigating fossil resource consumption (e.g., Gelfand et al. 2013). Waste cooking oil was used as the raw material for biodiesel to avoid the use of edible oil; however, it caused challenging issues for the product quality based on the conventional homogeneous alkali catalyst process due to the increase in the concentration of water and free fatty acid (FFA) in waste cooking oil (Abbaszadeh et al. 2012). A novel technology based on the ion-exchange resin catalyst process had been developed by academia as the next-generation process for biodiesel production with high conversion ratio and low impurities in the biodiesel fuel product (Shibasaki-Kitakawa et al. 2010; Shibasaki-Kitakawa et al. 2013). The esterification of FFA with methanol on the cation-exchange resin (Shibasaki-Kitakawa et al. 2015) and the trans-esterification of TAG with methanol on the anion-exchange resin (Shibasaki-Kitakawa et al. 2007; Shibasaki-Kitakawa et al. 2011; Yamazaki et al. 2016) had been verified with the qualities of biodiesel and glycerol.

Structural path analysis (Kikuchi et al. 2017b)

Using an input-output model (Leontief 1936; Leontief 1941), the domestic output of each industry can be estimated with the following equation (1):

$$\mathbf{x} = (\mathbf{I} - \mathbf{A})^{-1} \mathbf{y} \quad (1)$$

where $\mathbf{x} = (x_{if})$ is a matrix representing the domestic output of commodity i induced by final demand f , $\mathbf{I}$ is an identity matrix, $\mathbf{A} = (a_{ij})$ is an input coefficient matrix containing the ratios of the amount of input of commodity i directly required to produce one unit of a commodity j , and $\mathbf{y}$ is a matrix representing the final demand f for commodity i . $(\mathbf{I} - \mathbf{A})^{-1}$ is the Leontief inverse matrix, $\mathbf{L}$, where the elements of the matrix, $\mathbf{L} = (l_{ij})$, represent the demand for commodity i input directly and indirectly to produce one unit of commodity j . In other words, equation (1) represents the direct and indirect production of each commodity induced by each final demand. The Leontief inverse matrix $\mathbf{L}$ can now be converted into a series expansion as follows:

$$\mathbf{L} = (\mathbf{I} - \mathbf{A})^{-1} = \mathbf{I} + \mathbf{A} + \mathbf{A}^2 + \mathbf{A}^3 + \dots, \quad (2)$$

where $\mathbf{I}$ is the direct effect, or direct unit production amount demanded by final consumers. $\mathbf{A}$ is an indirect secondary effect indicating the amount of production required to produce products demanded by the direct effect. Substituting equation (2) into equation (1) gives us the following equation (3):

$$\mathbf{x} = \mathbf{y} + \mathbf{A}\mathbf{y} + \mathbf{A}^2\mathbf{y} + \mathbf{A}^3\mathbf{y} + \dots \quad (3)$$

Each right-hand term of equation (3) can be decomposed to elements that express supply chains. For example, the third term, $\mathbf{A}^2\mathbf{y}$, can be expressed as $a_{i^{(0)}i^{(1)}} a_{i^{(1)}i^{(2)}} y_{i^{(2)}f}$, where $i^{(k)}$ means the k -th sector originating in target product i ; i.e., $i^{(0)}$ means the sector of target product i . $a_{i^{(0)}i^{(1)}} a_{i^{(1)}i^{(2)}} y_{i^{(2)}f}$ represents a supply chain: industry $i^{(0)}$ (intermediate product) $\rightarrow$ industry $i^{(1)}$ (intermediate product) $\rightarrow$ industry $i^{(2)}$ (final product) $\rightarrow$ final demand f . As for $i^{(k)}$, the same sectors can be included as many times as needed because they can be recursively connected in a supply chain. This decomposition is the basis of the calculation in SPA (e.g., Defourny and Thorbecke 1984) and is applied in the quantification of the flow rate, $\text{FR}^{i^{(0)}}$ (JPY/year), of target products as the sum of all terms related to the supply chains originating in the target products - i.e., sectors in IO tables, as shown in equation (4) (Oshita and Kikuchi 2014).

$$x^{i^{(0)}} \approx \text{FR}^{i^{(0)},k} = \sum_{i^{(1)}}^N \sum_{i^{(2)}}^N \dots \sum_{i^{(k)}}^N \sum_f^F \left(y_{i^{(0)}f} + a_{i^{(0)}i^{(1)}} y_{i^{(1)}f} + a_{i^{(0)}i^{(1)}} a_{i^{(1)}i^{(2)}} y_{i^{(2)}f} + \dots + a_{i^{(0)}i^{(1)}} a_{i^{(1)}i^{(2)}} \dots a_{i^{(k-1)}i^{(k)}} y_{i^{(k)}f} \right) \quad (4)$$

N is the number of sectors adopted for all target products, F is the number of final demands specified by the adopted IO table version, k is the number of steps set at the execution of calculation, which starts from zero - i.e., $k = 0, 1, 2, \dots$ - and $x^{i^{(0)}}$ is the total output from the sector of target product $i^{(0)}$. When k is infinite, $\text{FR}^{i^{(0)},k}$ equals $x^{i^{(0)}}$. Each term,

$a_{i^{(0)}i^{(1)}} a_{i^{(1)}i^{(2)}} y_{i^{(2)}f}$, can be regarded as a flow and decomposed into paths from sector to sector (Kikuchi et al. 2017b). These paths can be summed up to streams which are parts of the cash-flow structures originating in the production of target products.

Settings in the customized IO table for Tanegashima

The survey and non-survey methods for constructing regional IO tables have been adopted and discussed in their selection for the application of IO analysis regarding the differences in the structures of developed IO tables (Stoeckl 2012), the estimation of coefficients (Lehtonen and Tykkyläinen 2014), and its verification (Bonfiglio and Chelli 2008). In this study, the non-survey method was basically adopted to create the basic economic structures and the specificities of Tanegashima were enhanced by applying the survey method. The IO table of Kagoshima Prefecture (2010) was used as the base table in this paper with the application of the IO table of Okinawa Prefecture (2010) and the Japan IO table as partly listed in Table 1. Open-sourced data on IO tables, such as REFIO (Moriizumi et al. 2015; Hondo et al. 2016), was also applied. Individual industrial records were also obtained from the Ministry of Internal Affairs and Communications, Japan, with an investigation of the Tanegashima sites to conduct the survey method for IO table construction.

The product prices of newly created sectors should be assumed for analyzing the cash flows updated by the technology implementation listed in Table 1. Based on the basic IO tables listed in Table 1, their productions, intermediate products, added values, inputs from source sectors, and outputs to final demands were estimated. The detail for the changes and settings in the related sectors are shown below. The massive implementation of NiTn18 resulted in a 1.66× increase in sugarcane production, 1.77× in raw sugar production, and 2.03× in bagasse production. The sugar seasons were lengthened from 4 months to 6.2 months with 4.8 months of power generation during nonsugar seasons. The price of heat (steam) from the bagasse-derived heat sector was assumed as one-third of heavy oil A in Japan, i.e., 0.376 JPY/MJ. The value of the feed-in-tariff in Japan for renewables (ANRE 2018) was adopted as the price for power generation derived from bagasse and wooden chips, i.e., 17 JPY/kWh and 25.9 JPY/kWh, respectively. The price of wooden chips was set by investigating the Tanegashima Forestry Cooperative at 9,000 JPY/t-wet (50wt%-water). Bioethanol was treated as the same quality as gasoline in heat quantity, which means that its price was set as the same as gasoline, i.e., 3.1 JPY/MJ. Regarding biodiesel, it was substituted for the diesel used for private transport at the factory, which is a welfare facility on Tanegashima. The demand for diesel was reduced by the technology implementation.

Survey design and settings

The sample was randomly drawn from the residents who were older than 20 years in Nishinoomote (hereafter Survey 1) and between 20 and 69 years of age in Nakatane and Minamitane (hereafter Surveys 2 and 3, respectively). The sample for Survey 1 was tailored to match the actual distributions of the population of each elementary school district and its gender, while that for Surveys 2 and 3 was drawn to reflect the actual gender and age for the population in the municipalities. For the detention survey, we obtained the cooperation of municipalities with sampling, distributing, and collecting questionnaires via their residents' association members. Residents' association members are those who distribute documents or newsletters from the municipality on scheduled dates. A few members are registered in such associations in each school district. The Minamitane municipality helped us with sampling, but we used the mail service for distributing and collecting questionnaires. The survey period for Surveys 1 and 2 depended on the scheduled working dates of residents' association members. For Survey 3, the questionnaire was sent on January 8, 2016. It is assumed that most of the respondents received the questionnaire on January 12, 2016 due to weekends and public holidays in between. The respondents were given 17 days to answer and post the questionnaire. Another survey was implemented to reveal their preferences towards heating energy in Nakatane (Survey 4), where the Tanegashima cane sugar mill is located and can provide excess bagasse-derived heat through district heating and cooling as discussed by Kanematsu et al.

(2017). Using a detention survey, all 3,584 households were research objects and the response rate was about 70%. In the same way as Survey 2, the questionnaire was sent via residents' association members. Respondents had 2 weeks to answer the questions.

The questionnaire for Surveys 1–3 consisted of four parts. The first part contained eight choice experiment questions. We asked respondents to assume that the electricity market was deregulated, and to choose one of the electricity plans listed in Table S4 as their most preferred. A “no change” option was included in the choice set to determine if a “status-quo bias” affected participants' responses. Each plan had four features: i.e., the power provider, energy mix, the monthly electricity fee, and the stability of the electricity supply (see Table S5). The power provider represents the type of firm generating and selling electricity. “Major providers” are general electricity utilities, like the Tokyo Electric Power Company (TEPCO) or the Kyushu Electric Power Company (KEPCO). Other power providers are new entrants to the market, and could be regional, domestic, or foreign-based firms that use regional, domestic, and foreign resources for generating electricity, respectively. Energy mix has four levels that were Mix 1 to Mix 4, where: “Mix 1” resembles the current energy mix in Japan wherein most power is generated from thermal power plants based on fossil fuels. “Mix 2” includes electricity converted from fossil fuels and nuclear energy in a proportion similar to the energy mix in Japan before the Fukushima incident. “Mix 3” is comprised of fossil fuels, nuclear energy, and renewable resources, set in proportion to the ideal energy mix for 2030, as indicated in the Japanese Ministry of Economy, Trade and Industry's (2015) *Long-term Energy Supply and Demand Outlook*. “Mix 4” is characterized by a substantial increase in reliance on renewable energy and no use of nuclear energy. We set the monthly electricity fee at four rates: 6,000 JPY (20 JPY per kWh), 5,700 JPY (19 JPY per kWh), 6,300 JPY (21 JPY per kWh), and 6,600 JPY (22 JPY per kWh). To determine these four levels, we set 300 kWh as the monthly electricity consumption, which reflects the average household consumption of energy per month in Japan, according to the report of the Federation of Electric Power Companies of Japan (<http://www.fepc.or.jp/library/pamphlet/zumenshu/pdf/all.pdf>). Stability of supply indicates the possibility of a sudden decrease of power voltage in electricity service. The second part of the questionnaire directly asked respondents to select three important factors for choosing electricity plans from 18 features, such as monthly electricity fee, ease of understanding the contract fee, and the quality of customer service (see Table 4). The third part asked respondents their preference for regional renewable resources to generate electricity. They had to select three resources from a total of eight resources that seem feasible for local electricity generation: i.e., sunlight, wind power, geothermal power, small- and medium-sized hydraulic power, wave power, bagasse, wooden chips, and livestock waste. The last part of the questionnaire consisted of demographic questions that asked about their gender, age, educational background, occupation, type of business, and annual household income.

The questionnaire for Survey 4 mainly comprised of six parts. Firstly, the respondents were asked to answer their comprehension regarding combined heating and power, and district heating and cooling systems. The conditions included whether they would renew the hot water dispenser with one with a better efficiency, which included energy efficiency, operating cost, size, weight, and its effects on the environment and regional economy. The acceptable payback time was also asked. They had to select three from nine resources that seem feasible for local energy supply: i.e., sunlight, wind power, geothermal power, small- and medium-sized hydraulic power, wave power, bagasse, wooden chips, livestock waste, and others. The fifth part of the questionnaire asked respondents to select three important factors for choosing energy for household consumption from 18 features, such as monthly energy costs or ease of understanding the contract fee (see Table S6). Finally, we asked about their individual attributes using the same questions as for Surveys 1 to 3.

Table S9 shows the descriptive statistics of gender and age per survey for Surveys 1–4, respectively. The results indicate that our sample does not include many respondents from the younger generation, especially those in their twenties. Except for Survey 1, the proportion of

male respondents is somewhat larger than that of the female respondents. Table S10 and Table S11 represent descriptive statistics on their education levels and annual household incomes, respectively. The majority of respondents graduated from high school as their final academic background. Around 10% hold bachelor's or higher degrees, which is substantially lower than the Japanese average. Regarding annual household income, the largest proportion of samples for Surveys 1 and 4, and the one for Surveys 2 and 3 are the lowest level and second lowest, respectively. The average household income on Tanegashima is much lower than the Japanese average.

Figures and Tables

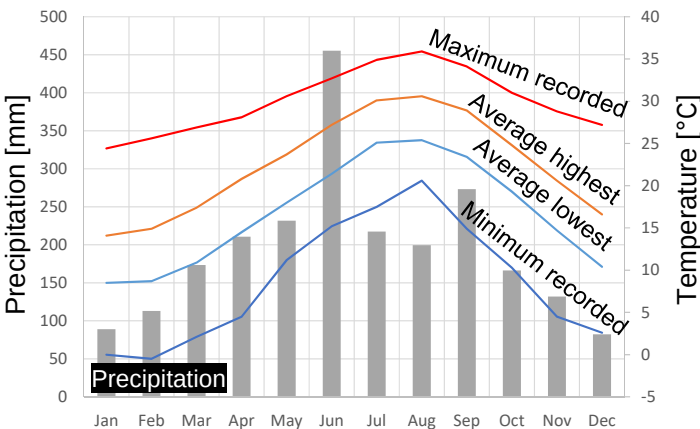


Fig. S1 Climate conditions for Tanegashima: precipitation and temperature

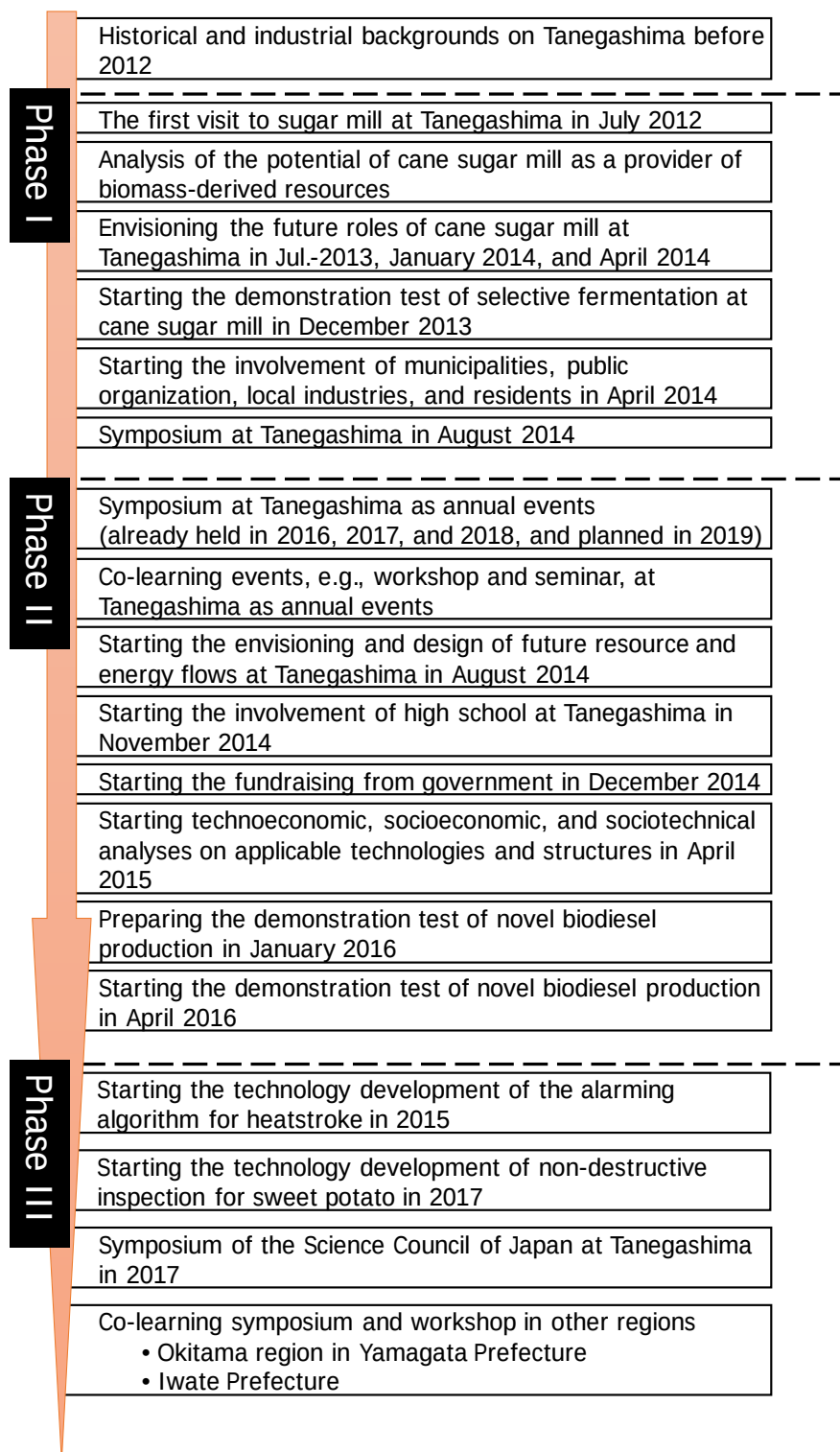
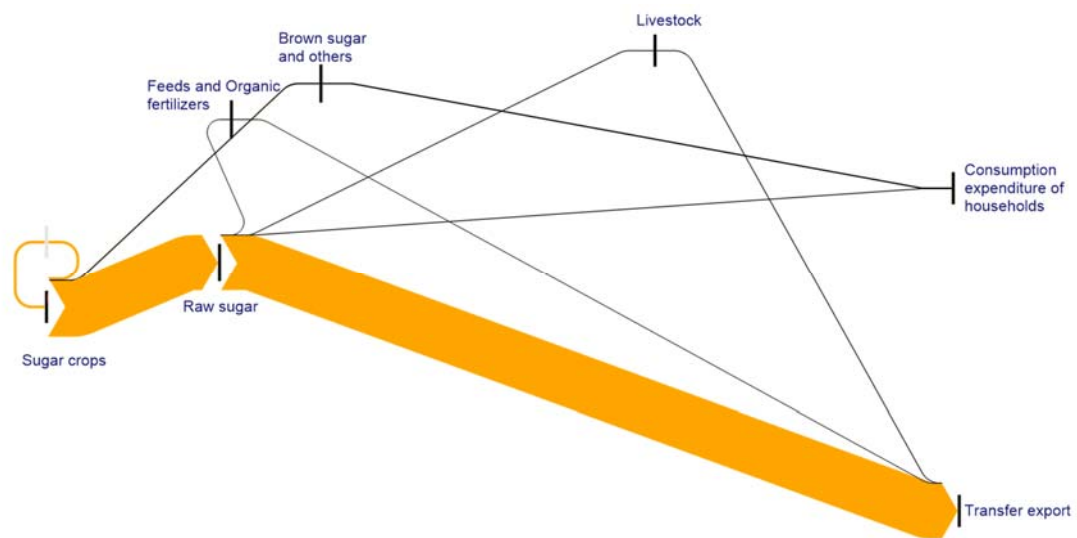
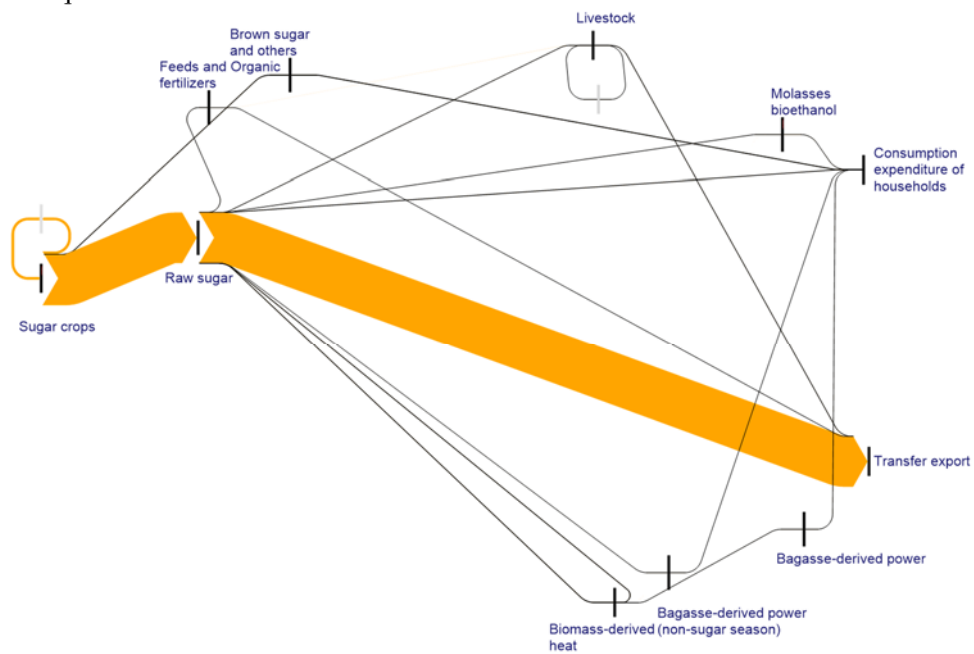


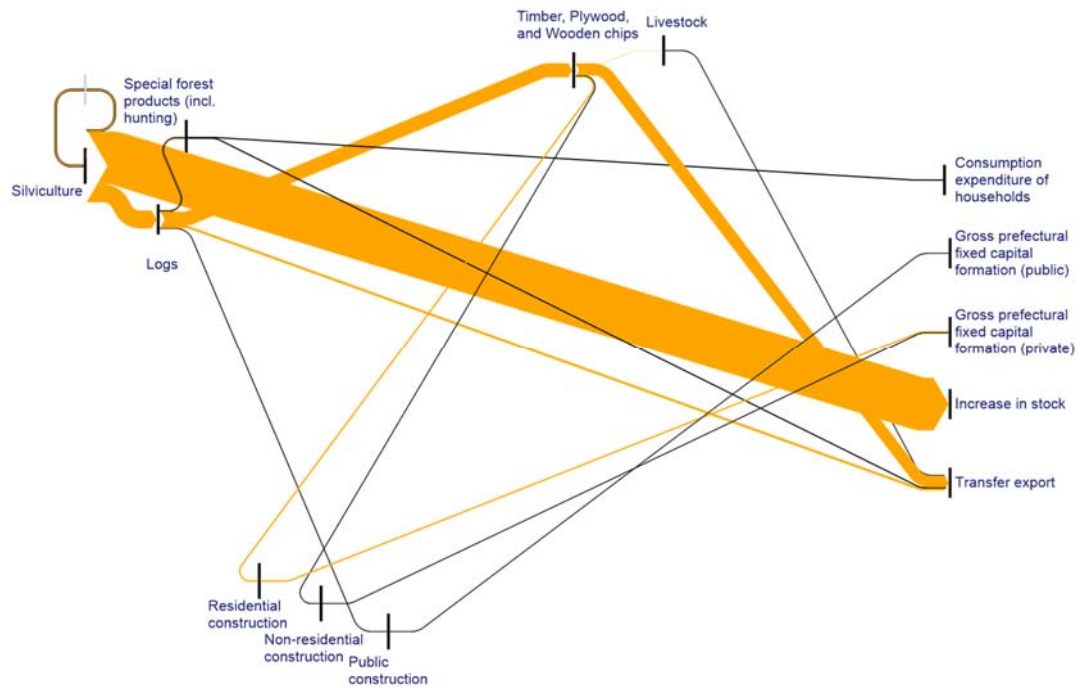
Fig. S2 Events at Tanegashima related with major co-learning opportunities



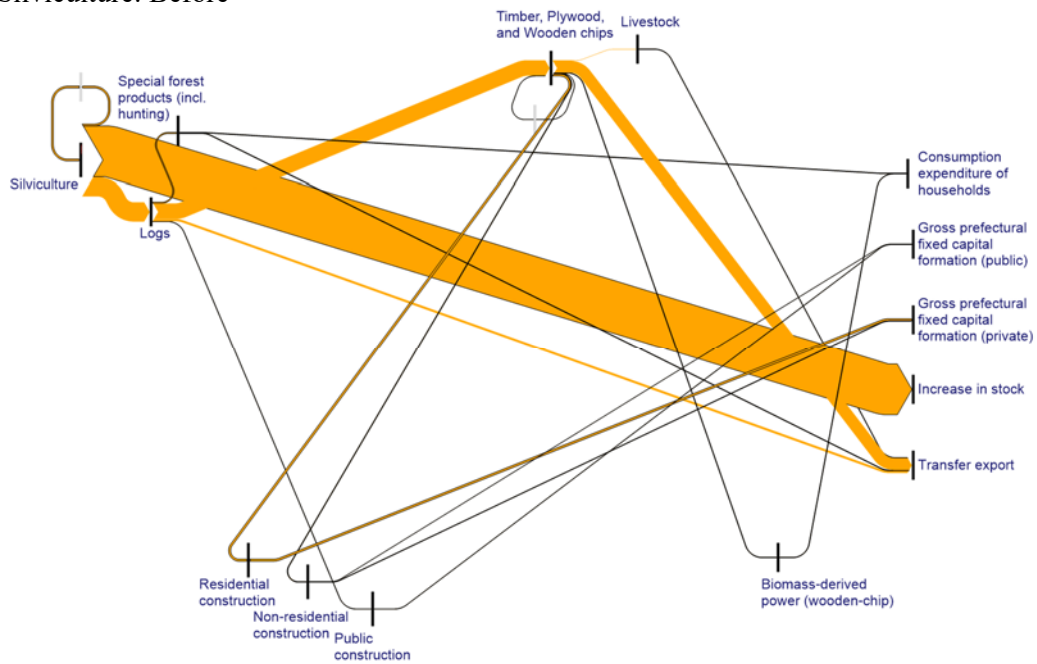
(a) Sugar crop: Before



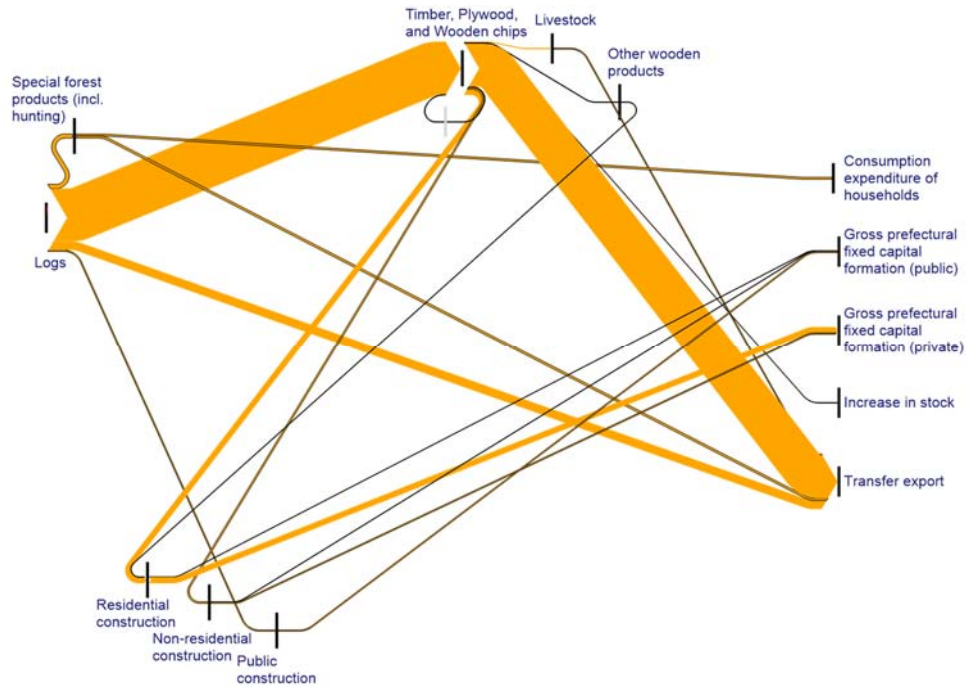
(b) Sugar crop: After



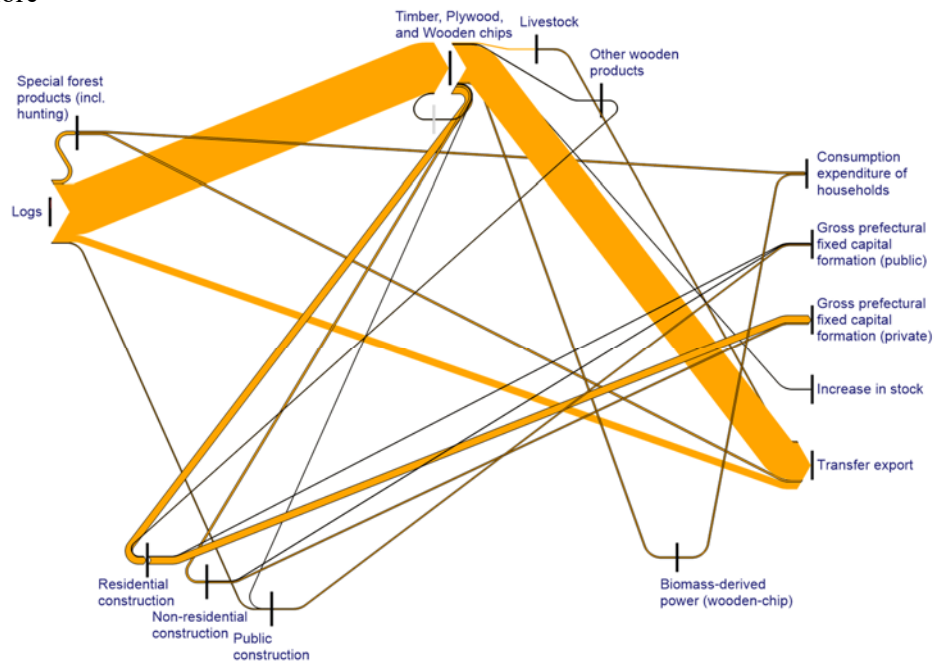
(c) Silviculture: Before



(d) Silviculture: After



(e) Log: Before



(f) Log: After

Fig. S3 Cash flow diagrams of Sugar crop, Silviculture, and Logs as the paths among sectors visualized by the SPA based on the Tanegashima-customized IO table

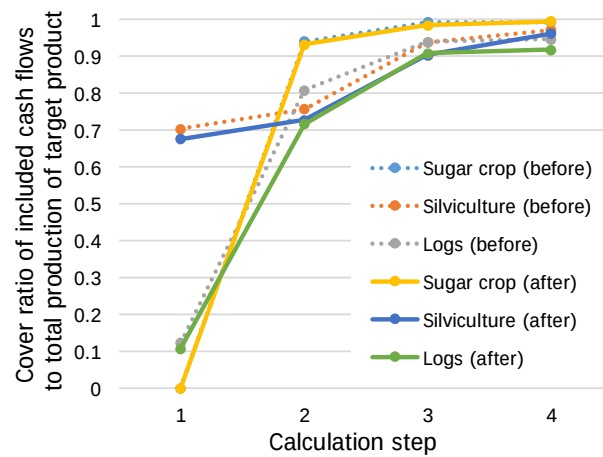


Fig. S4 Calculation steps for Sugar crop, Silviculture, and Logs in SPA

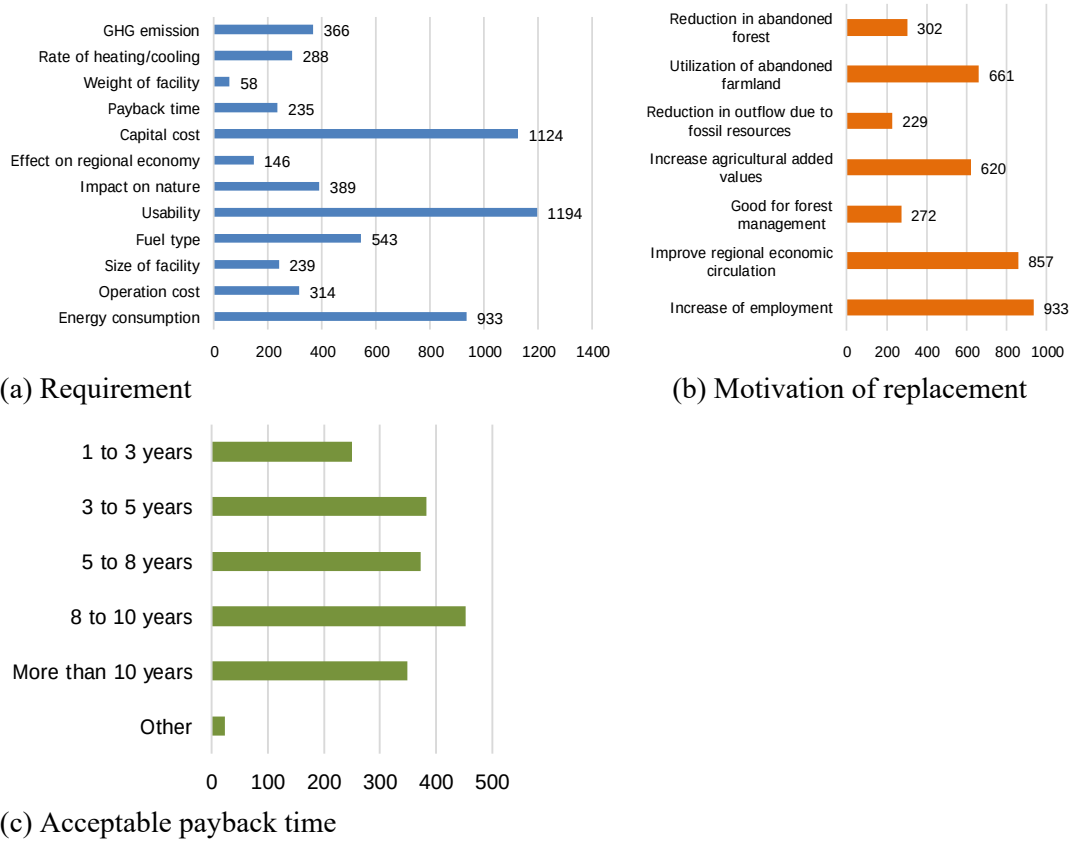


Fig. S5 Responses on thermal energy systems to be used on Tanegashima obtained through Survey 4

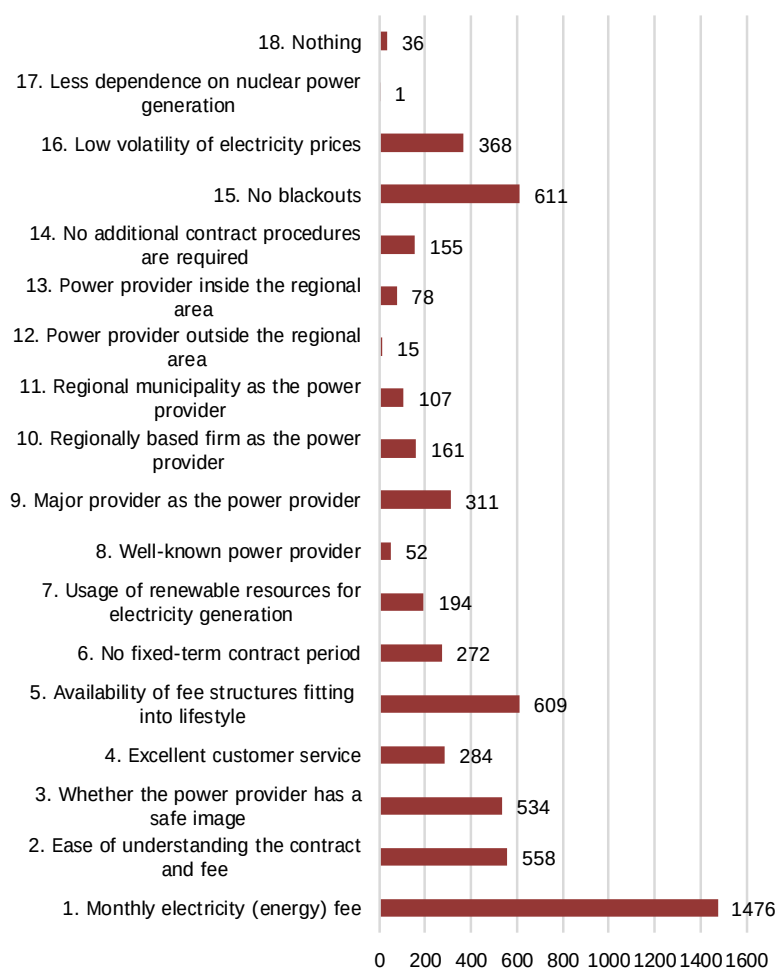


Fig. S6 Responses on important points to be considered in residents' decision of energy for use obtained through Survey 4

Table S1 Basic information on Tanegashima (Kagoshima Prefecture 2017)

Area	453.96 km ² (fifth largest remote island in Japan)	
Coordinates	30°35'N, 130°59'E	
Population (2015)	29,847	
Climate	Subtropical climate (see also Fig. S1) Average yearly temperature: 19.4°C Annual precipitation: 4472 mm	
Forest area	241.94 km ²	
Cultivated area	88.50 km ²	
Industry (2015)	Population by industry [persons] Total: 16,653 (Primary 4,737; Secondary 1,994; Tertiary 9,922) Gross production [million yen] Total: 92,681 (Primary 8,478; Secondary 11,776; Tertiary 71,690) Agricultural production [%] Rice: 4.35, Sweet potato: 7.90, Vegetables: 18.47, Fruits: 0.67, Sugarcane: 18.71, Industrial crops: 4.00, Flowers: 3.32, Livestock: 42.52	
Power grid	Plant	Kyushu Electric Power Company: Tanegashima 1st power plant: Diesel engine (1.5 MW, 3 MW, 3 MW, 4.5 MW, 4.5 MW) Shin-Tanegashima power plant: Diesel engine (6 MW, 6 MW, 6 MW, 6 MW)
	Demand in 2011	Fuel: 35,924 kL/year (2011FY) (1,473,984 GJ/year) Generated power: 156,759 MWh/year
	Capacity	1,600 t-cane/day
Cane sugar mill	Energy plant	Boiler: Natural-circulation water tube boiler Bagasse and heavy oil 35 t-steam/hour Power generation turbine: Back-pressure turbine, 9,733 rpm, 1,750 kW

Table S2 Major co-learning opportunities created on Tanegashima mainly during the 2014 and 2015 fiscal year.

Organization	Opportunities
Municipalities, i.e., Nishinoomote, Nakatane, Minamitane, and Kagoshima Prefecture	26/5/2014: Municipal employees, 30 persons to discuss the need for the concept of regional resource circulation for the future of Tanegashima through a seminar. 1/12/2014: Kumage Branch of Kagoshima Prefectural government, 6 persons to discuss the need for the concept of regional resource circulation for the future of Tanegashima through a seminar 19/12/2014: Workshop with young Nishinoomote municipality staff, 30 persons to discuss the need for and generate actions for the establishment of regional resource circulation by applying the KJ method (Scupin, 1997) 19/8/2015–27/8/2015: Workshop with agriculture, forestry, and fisheries divisions of Nishinoomote, 3 persons to discuss the need for and concerns about actual procedures to gather regional resources for materials and energy use in Tanegashima by applying the KJ method (Scupin, 1997) 14/9/2015: Workshop with Nishinoomote municipality staff, 20 persons to generate the scenario plans for implementing the envisioned material and energy flows in Tanegashima (Fig. 3) by applying the KJ method (Scupin, 1997)
Public organization to discuss the need for and concerns about actual procedures for implementing the envisioned material and energy flows in Tanegashima (Fig. 3) based on lectures and questionnaires	13/6/2014: Tanegashima Forestry Cooperative, 5 persons 31/7/2014: Superintendents of school areas, 15 persons 31/7/2014: Councilpersons, 6 persons 1/8/2014: Commerce and industry association, 25 persons 1/12/2014: Technology council: Livestock division, 20 persons 1/12/2014: Tanegashima–Yakushima Agriculture Cooperative, 6 persons 19/1/2015: Commercial avenue and residents, 40 persons 27/2/2015: Tanegashima medical association, 20 persons
Tanegashima High School (http://taneko.edu.pref.kagoshima.jp/category/bunrui/bunrui31/) including a few events after 2016	14/11/2014: Consultation of and discussion on collaboration between high school and universities, principal and vice-principal 12/3/2015: Plenary lecture for all students (over 200) to discuss current issues and future possibilities concerning social problems in Tanegashima 3/7/2015: Lecture for the third year in literature and science (40 students) to discuss the performance and possibilities of technology options applicable in Tanegashima 3/7/2015: Plenary lecture for the first year (140 students) to discuss current issues and future possibilities concerning social problems in Tanegashima 3/7/2015: Lecture for the second year in literature and science (40 students) to discuss the performance and possibilities of technology options applicable in Tanegashima 30/9/2015: Lecture for the second year in literature and science (40 students) to discuss the performance and possibilities of technology options applicable in Tanegashima 16/12/2015: Lecture for the second year in literature and science, 40 students, to learn how to analyze the local economic circulation through Regional Economy Society Analyzing System (https://resas.go.jp/#/12/12100) 26/1/2016: Lecture for the third year in literature and science, 40 students, to discuss the performance and possibilities of technology options applicable in Tanegashima. 26/1/2016: Lecture for the second year in literature and science, 40 students, to discuss the performance and possibilities of technology options applicable in Tanegashima

	26/1/2016: Lecture for the second year in electrical department, 30 students, to discuss the performance and possibilities of technology options applicable in Tanegashima. 29/1/2016: Lecture for the second year in electrical department, 30 students, to discuss the performance and possibilities of technology options applicable in Tanegashima and to learn the ion-exchange resin catalyzed biodiesel production. 29/1/2016: Lecture for the second year in biological production department, 30 students, to discuss the performance and possibilities of technology options applicable in Tanegashima. 20/12/2017: Workshop at the University of Tokyo for the second and the first year in literature and science with the students from Sado High School, another remote island in Japan, to generate scenario plans for implementing the envisioned material and energy flows in Tanegashima (Fig. 3) and Sado island by applying the KJ method (Scupin, 1997) (http://www.sustainability.k.u-tokyo.ac.jp/ja/events/4868.html) 14/12/2018: Workshop at the University of Tokyo for the second and the first year in literature and science with the students from Sado High School, another remote island in Japan, to generate scenario plans for implementing the envisioned material and energy flows in Tanegashima (Fig. 3) and Sado island by applying the KJ method (Scupin, 1997) (http://taneko.edu.pref.kagoshima.jp/archive/2018/)
Symposiums incl. events after 2016 (http://www.city.nishinoomote.lg.jp/admin/soshiki/keizai_kankoka/shoukouseisaku/ecoisland/symposium/symposium/index.html)	2/8/2014: 165 attendees, lectures and questionnaire 24/2/2016: 50 attendees, lectures and questionnaire, http://www.furusato-tanegashima.net/tanegashima/nw/satoyama-satoumi-seminar.html 6/3/2016: 150 attendees, lectures & questionnaire on Tanegashima projects, reporting of scenario analysis from high school students, and demonstration of ion-exchange resin catalyzed biodiesel production and thermal storage by zeolite 11/3/2017: 150 attendees, lectures & questionnaire on Tanegashima projects, and reporting of scenario analysis from high school students 3/3/2018: 200 attendees, lectures & questionnaire on Tanegashima projects, reporting of scenario analysis from high school students 9/3/2019: 200 attendees, lectures & questionnaire on Tanegashima projects, reporting of scenario analysis from high school students

Table S3 Construction of the IO table for Tanegashima

Sectors in Kagoshima IO table	Sectors in Tanegashima IO table	Estimation ways of input coefficient
Sectors in agriculture, forestry, and fisheries except for the following sectors in this table		Based on the actual production and added values within Tanegashima (Kagoshima Prefecture 2013, 2017)
Manufacturing sectors except for the following sectors in this table		Shipments, the number of workers (METI 2014), and individual industrial statistics
Sectors in water supply and waste treatment		Based on the local conditions of water supply (MLIT 2014) and waste treatment (Kagoshima Prefecture 2016a)
Sectors in medical and welfare services		Based on the local conditions of water supply (MHLW 2017) and waste treatment (Kagoshima Prefecture 2016b)
Potatoes and pulses	Potatoes and sweet potatoes	Potatoes and sweet potatoes from Japan IO table
	Pulses	Pulses from Japan IO table
Other edible crops	Sugar crop	Sugar crop from Okinawa IO Table
	Other edible crops	Other edible crops from Kagoshima IO table
Sugar, oils, condiments, and seasonings	Raw sugar	Converted from Sugar from Okinawa IO table based on the investigation of the cane sugar mill
	Brown sugar and other sugars	Based on the investigation of the plants
	Starch	Starch from Japan IO table
	Refined sugar, oils, and condiments and seasonings	Sugar, oils, condiments, and seasonings from Kagoshima IO table
Petroleum refinery products	Gasoline	Based on the fuel consumption statistics (MLIT 2013) and islands statistics (CRPJI 2014)
	Diesel	
	Other petroleum refinery products	Petroleum refinery products from Kagoshima IO table
Electricity	Power generation	Financial reports and settlement of OEPCO (2006, 2007)
	Transmission, transformation, and distribution	

Table S4 An example of a choice set in the choice experiment

	Plan A	Plan B	Plan C
Power provider	Major provider	Domestic firm	
Energy mix	Fossil fuels 80% Nuclear 20%	Fossil fuels 100%	
Monthly electricity fee	6,000 JPY (20 JPY/kWh)	6,300 JPY (21 JPY/kWh)	Continue the current contract
Stability of energy supply	Always stable	Possible momentary power failure once per year	
Choose one			

Table S5 Electricity supply attributes and levels

Attributes	Levels			
Power provider	Major provider	Regional firm	Domestic firm	Foreign firm
Energy mix	Mix 1 (Fossil fuels 100%)	Mix 2 (Fossil fuels 80%, nuclear 20%)	Mix 3 (Fossil fuels 50%, renewables 30%, nuclear 20%)	Mix 4 (Fossil fuels 80%, renewables 20%)
Monthly electricity fee	5,700 JPY (19 JPY /kWh)	6,000 JPY (20 JPY /kWh)	6,300 JPY (21 JPY /kWh)	6,600 JPY (22 JPY /kWh)
Stability of energy supply	Always stable	Possible momentary power failure once per year	Possible blackouts for 10 minutes once per year	Possible blackouts or momentary power failure caused by inclement weather

Table S6 Attributes of electricity (energy for Survey 4) options that survey respondents could choose as “important”

Attributes	
1. Monthly electricity (energy) fee	10. Regionally based firm as the power provider
2. Ease of understanding the contract and fee	11. Regional municipality as the power provider
3. Whether the power provider has a safe image	12. Power provider outside the regional area
4. Excellent customer service	13. Power provider inside the regional area
5. Availability of fee structures fitting into lifestyle	14. No additional contract procedures are required
6. No fixed-term contract period	15. No blackouts
7. Usage of renewable resources for electricity generation	16. Low volatility of electricity prices
8. Well-known power provider	17. Less dependence on nuclear power generation
9. Major provider as the power provider	18. Nothing

Table S7 Historical events and the status of technology implementation on Tanegashima

Category	Technology implementation
Historical events	Historically, Tanegashima had accepted new technology implementation as the Portuguese arquebus in 1543, the Tanegashima Space Center spaceport in 1969, or tobacco access age passport (TASPO) in 2004 before 2008 when all of Japan had implemented the passport (MHLW 2006).
Cane sugar mill	Regarding the sugarcane industry, technological demonstrations had been challenged on Tanegashima by Asahi Group Holdings Ltd. on sugarcane cultivar improvement (Ohara et al. 2009) and selective fermentation for inverse processing of sugar and ethanol (Ohara et al. 2012). Thanks to the Tanegashima Sugarcane Breeding Site, one of the sites of Kyushu Okinawa Agricultural Research Center in National Agriculture and Food Research Organization, Japan, sugarcane cultivar improvement had become feasible as a technology option. The climate condition on Tanegashima is not suitable for sugarcane farming with their low temperature. While the precipitation there is relatively higher than for other sugarcane areas in Japan such as Okinawa Island, it is much less than equatorial regions. In other words, Tanegashima is one of the most difficult areas in the world for a sugarcane industry. Nevertheless, the industry can be operated, which is largely a result of efforts by the cane sugar mill and farmers. Based on the nature of people on Tanegashima, they have the capabilities to accept new technologies and structures in the sugarcane industry. This is also an important background in regional specification.
Biodiesel production site	As for the current regional systems on Tanegashima, waste cooking oils had been converted into biodiesel by conventional homogeneous alkali catalyst methods on Tanegashima (Chen et al. 2017). The collection routes structures of waste cooking oils had already been constructed on Tanegashima. Forestry systems also existed on Tanegashima, although they are now shrinking due to the decrease in the demand for timber.

Table S8 Core players involved in the Tanegashima case. The definition of “core” players is set as those who religiously visit Tanegashima with their own funds, conduct research activities, and join the co-learning communities

Involved phase	Affiliation and expertise	Activity on Tanegashima
Beginning of phase I	The University of Tokyo: chemical system engineering, process systems engineering	Facilitation of co-learning communities; Analysis of sugar mill and energy systems
	National Chung Kung University (Tohoku University from Aug 2014): environmental engineering, chemical system engineering	Facilitation of co-learning communities; Analysis of sugar mill and energy systems
	Kyushu Okinawa Agricultural Research Center, National Agriculture and Food Research Organization: Agriculture	Breeding of sugarcane cultivars
Phase I	Kobe University: environmental economics	Construction of customized Tanegashima IO table; IO analysis; Structural path analysis
Phase II	The University of Tokyo: behavioral economics	Questionnaire surveys on preferences; Management of workshops
	The University of Tokyo (Wakayama Prefectural government): forestry engineering	Analysis on forestry
	Waseda University: mechanical engineering	Technology development of thermal storage, transport, and utilization
	Tohoku University: reaction engineering	Technology development and demonstration of biodiesel production by ion-exchange resin catalyst process
	Renewable energy consultation company	Supporting municipalities plan regional energy systems development
	Process engineering company	Construction and maintenance of biodiesel production plants based on ion-exchange resin catalyst process
Phase III	Kyoto University: machine learning Kumamoto University: medical electronics Nara Institute of Science and Technology: medical doctor	Technology development of the alarming algorithm for heatstroke
	Kyoto University: Human system engineering	Technology development of non-destructive inspection for sweet potato
	University of Tsukuba School of Integrative and Global Majors	

Table S9 Descriptive statistics on gender and age

	Survey 1 Nishinoomote		Survey 2 Nakatane		Survey 3 Minamitane		Survey 4 Nakatane	
	Male	Female	Male	Female	Male	Female	Male	Female
20–29	18 (6%)	16 (4%)	7 (6%)	10 (10%)	10 (6%)	9 (6%)	15 (1%)	24 (2%)
30–39	38 (12%)	57 (15%)	17 (15%)	26 (25%)	26 (16%)	25 (17%)	90 (7%)	103 (10%)
40–49	65 (20%)	83 (22%)	27 (23%)	26 (25%)	27 (16%)	27 (18%)	146 (12%)	139 (13%)
50–59	104 (33%)	93 (25%)	38 (32%)	26 (25%)	42 (25%)	37 (25%)	262 (22%)	179 (17%)
60–69	93 (29%)	128 (34%)	28 (24%)	15 (15%)	60 (36%)	51 (34%)	330 (27%)	218 (21%)
70–79	-	-	-	-	-	-	211 (18%)	191 (18%)
80–89	-	-	-	-	-	-	139 (12%)	154 (15%)
90–99							8 (1%)	25 (2%)
Total	318	377	117	103	165	149	1,201	1,033

Table S10 Descriptive statistics on education background

	Survey 1 Nishinoomote		Survey 2 Nakatane		Survey 3 Minamitane		Survey 4 Nakatane	
	Freq	%	Freq	%	Freq	%	Freq	%
Elementary school/ junior high school	70	10	11	5	18	6	427	20
High school	373	53	122	54	181	55	1,101	50
Professional school	90	13	37	16	47	14	254	12
College	64	9	24	11	27	8	130	6
University	84	12	31	14	46	14	216	10
Postgraduate school	5	1	1	0	3	1	16	1
Other	13	2	1	0	5	2	39	2
Total	699		227		327		2,183	

Table S11 Descriptive statistics on annual household income

	Survey 1 Nishinoomote		Survey 2 Nakatane		Survey 3 Minamitane		Survey 4 Nakatane	
	Freq	%	Freq	%	Freq	%	Freq	%
Less than or equal to 2 million JPY	286	42	40	18	71	23	709	36
2–3.9 million JPY	239	35	92	41	113	36	649	33
4–5.9 million JPY	101	15	51	23	78	25	342	17
6–7.9 million JPY	36	5	25	11	32	10	170	9
8–9.9 million JPY	11	2	10	4	14	4	40	2
More than 10 million JPY	5	1	6	3	7	2	64	3
Total	678		224		315		1,974	

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