MSc Program
Renewable Energy Systems

Proceeding the transition to renewable energy systems in Tottori

A Master's Thesis submitted for the degree of
"Master of Science"

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October 2017, Vienna

Affidavit

I, SHINJI KOMORI, hereby declare

1. that I am the sole author of the present Master's Thesis, "PROCEEDING THE TRANSITION TO RENEWABLE ENERGY SYSTEMS IN TOTTORI", 78 pages, bound, and that I have not used any source or tool other than those referenced or any other illicit aid or tool, and
2. that I have not prior to this date submitted this Master's Thesis as an examination paper in any form in Austria or abroad.

Vienna, 11.10.2017

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Signature

Abstract
Many countries, cities and areas have been successfully approaching 100% renewable energy. A lot of knowledge have been obtained in that effort.
On the other hand, it is not high level the target of switching from fossil fuels to renewable energy in Japan. For this reason, local municipalities are not clearly showing specific targets of renewable energy introduction. Research institutions such as national and universities have data on the introduction status of renewable energy in each region and future possibilities and it is possible to consider switching to 100% renewable energy.
In this research, utilizing the experiences of energy transformation in the world, we are planning to switch to 100% renewable energy in a certain area of Japan. The transformation will develop the environment, the economy and the job creation, at same time It prevent global warming.
And then I would like to accelerate the shift to renewable energy in Japan.


Mt. Daisen [1]


Yonago Mizutori Park for bird watching[2]

[1] http://www.tottori-guide.jp/tourism/tour/view/198
[2] http://www.tottori-guide.jp/tourism/tour/view/236

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1 Introduction

1.1 Motivation

I worked at the office in Tokyo when Fukusima big earthquake happened. I saw the many tall buildings were swayed long time and then I lived in the planned blackout town. I noticed the energy is very important and would like to promote to change from fossil to renewable energy. But Japan government renewable energy target is very low and the government is restarting nuclear power plants.

There are many cities, towns and regions which have reached a self-sufficient energy supply in the world. These regions are not only successful to change from fossil fuel to renewable sources in the region, but also growing in the local economy and increasing population. On the other hand, many regions have difficulties to decrease fossil fuel consumption by economical, technical reasons and human resources.

There are many books for renewable energy, but most of them explain the technical information, for example, Biomass, Solar Energy, Wind Energy, Geothermal Energy and so on.

1.2 Core objectives of this work

The core objectives of this report are to answer the following questions for specific regions.

- How to fix the 100%RE target in the region?
- How much money is flowing out for fossil fuel?
- How much GHG are emitted?
- How much money will be needed for investment and O&M of RE plants?
- How to organize people to proceed the transition to RE systems?

1.3 Structure of this report

100% renewable energy supply regions have been successful to decrease fossil fuel consumption and create new economy. In this report the reasons of the area will be analyse how to proceed and a district which consumes much oil and coal will be transformed into a renewable energy one.

There are many statistic data about energy included renewable one in the library on the Japan government organization websites. I choose a small country Tottori Prefecture. According to use the data and knowledge of these 100% RE region projects, I will fix the 100% RE target and show how much money and GHG emission flow out from the region.

Most important is to decide a 100%RE self-sufficient target setting and to show a money flow for fossil fuel. Finally, it is calculated how much money the people need to pay the investment and O&M costs and to get income of electricity and heating.

2 Background

Regions where all energy supply is switched from fossil to renewable energy are expanding all over the world, and a lot of knowledge is obtained in the process. It is said that energy efficiency improvement and usage reduction are the first important initiatives.

Even in Japan, many renewable energy facilities have been installed by feed-in tariff (FIT) after the Fukushima big earthquake, but the RE ratio has never been a high value both for the present situation and the target.

2.1 **100% RE sits**

Knowledge of a hundred percent renewable energy region projects 166 regions are succeeding to transform to 100%RE (Table 2-1). “Country opportunities vary, but each country has a role to play in scaling up renewables” is described in this report. It’s means that a lot of information for RE projects proceeding is able to be collected.

Table 2-1 Go 100% renewable energy sits shows many RE projects proceed in the world.[3]

Region	Projects Number	Region	Projects Number
Africa	12	Australia	8
Asia	8	North America	42
Europe	86	South America	4
Indian Ocean	1	South Pacific Ocean	5

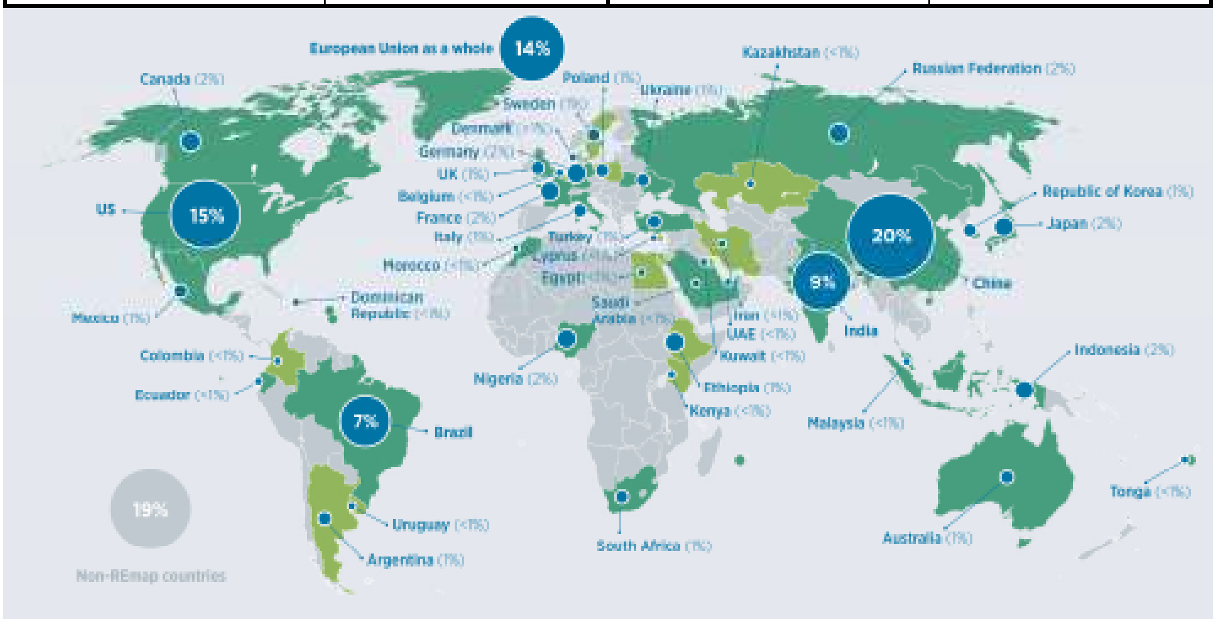

Fig. 2-1 Share of modern renewables in energy use of Remap countries, 2013-2030 [4]

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[3] Author counts the number of projects, the renewables 100 policy institute: http://www.go100percent.org/cms/ accessed 20 September 2017

[4] Gielen D. et al: IRENA; REmap – 2016 – edition report: http://www.irena.org/DocumentDownloads/Publications/IRENA_REmap_2016_edition_report.pdf accessed 2 May 2017

2.2 What has been analysed on the topic worldwide?

2.2.1 Knowledge of 100% RE projects

Information was used from two reports which are "Linking Renewable Energy to rural development (2012) OECD" [5]and "How to achieve 100% renewable energy; World Future Council, September 2014."[6]

"Linking Renewable Energy to rural development" reports below.

Key findings: Potential Benefits for Rural Regions

- Jobs and business opportunities
- New revenue sources
- Downstream activities and innovation systems
- Capacity building and community empowerment
- Affordable energy (heat, electricity, fuel)

Local and Regional Policies to stimulate RE Innovation

- Regional targeted RE innovation activities
- Competence development -education and training investment
- Investment in RE R&D facilities and activities
- Marketing, branding and promotion of RE
- Municipal/ regional government ownership of RE production facilities or energy utilities
- Physical planning controls
- Local taxation
- Influence on national policies
- Investment incentives for RE
- Sustainability objectives

John M Bryden, Linking RE to Rural Dev. "Issues from the OECD study and Report", Dec.2012

[5] OECD Green Growth Studies (2012): Linking Renewable Energy to Rural Development. http://www20.iadb.org/intal/catalogo/PE/2012/10377.pdf accessed 9 October 2017

[6] Toby D. Couture et al.: How to Achieve 100% Renewable Energy. (2014): http://www.medspring.eu/sites/default/files/How-to-achieve-100-percent-renewable-energy.pdf, accessed 16 May 2017

“How to achieve 100% renewable energy” reports below.

<Five key findings>

1) Achieving 100% RE can generate significant cost saving
2) 100% strategies are not just for the wealthiest countries
3) Transitioning to 100% RE can mitigate risks and make countries more resilient
4) Committing 100% RE can generate new economic activity, create jobs and improve life quality
5) Achieving a fully 100% RE system will require significantly expanding transport sectors

<Recommendations for policy makers>

1) Make energy efficiency a top priority
2) Electrify the heating/cooling and transport sectors
3) Maximize opportunities for citizen participation and the development of new business models
4) Educate and inform citizens and businesses
5) Adopt an integrated approach to fiscal, economic and energy policy

When a 100% renewable energy project proceeds in a specific region, following ten points are important.

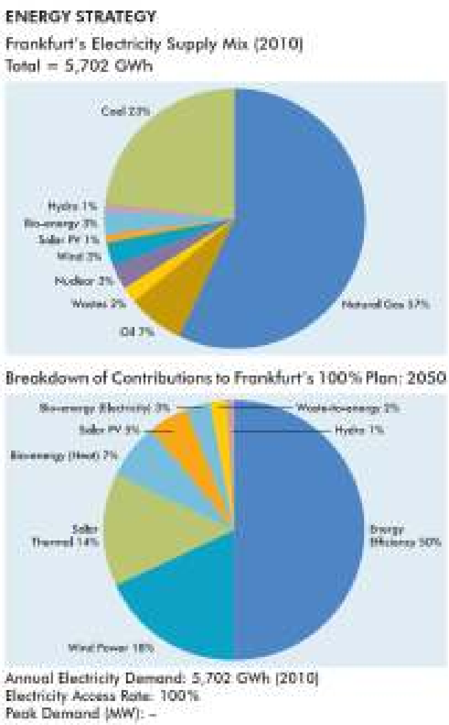
1) Regionally targeted RE innovation activities
2) Municipal/ regional government ownership of RE production facilities or energy utilities
3) Investment in RE R&D facilities and activities
4) Competence development -education and training investment
5) Marketing, branding and promotion of RE
6) Make energy efficiency a top priority
7) Electrify the heating/cooling and transport sectors
8) Maximize opportunities for citizen participation and the development of new business models
9) Educate and inform citizens and businesses
10) Adopt an integrated approach to fiscal, economic and energy policy

2.2.2 Knowledge of Energy Efficiency

When the energy system is changed by switching from fossil fuels to renewable energy, firstly the energy efficiency should be improved and the energy consumption should be reduced.

Energy strategy in Frankfurt is very challengeable. The target is firstly 50%, energy consumption will be decreased by high energy efficiency.

Average Temperature Range	-1 Celcius to 26 Celcius
Size (sq. km)	248.3 km²
Population Size	687,775 (2012)
Political Status	City



(a) Frankfurt information (b) Frankfurt's Energy Strategy

Fig.2-2 Frankfurt's Energy Strategy [7]

[7] Toby D. Couture et al.: How to Achieve 100% Renewable Energy. (2014): http://www.medspring.eu/sites/default/files/How-to-achieve-100-percent-renewable-energy.pdf, accessed 16 May 2017

In the report of “Long-Term Scenarios for Decarbonizing Japan[8]” shows that it is possible to decrease a half energy consumption in 2050 by high energy consumption and Japan’s population downward.
Key technologies of energy efficiency in household sector are four points(Table 2-2).

- Promotion of zero energy house (ZEH)
- Heat pumps
- LED lighting
- Refrigerators

Table 2-2 Key technologies and measures for energy efficiency[9]

Sector	Examples of technologies and measures
Industry	Inverter controls on pumps, inverter controls on fans, iron/steel recycling
Household	Promotion of zero energy houses (ZEH), heat pumps, and LED lighting, more efficient electric refrigerators, reduced standby energy consumption
Commercial	Promotion of zero energy buildings (ZEB), replacement of hard-disk storage in data centers with flash memory
Transport	Promotion of eco-friendly driving, car sharing, electric vehicles (EV), and fuel cell vehicles (FCV)

[8] Research Institute for Systems Technology (2017): Long-Term Scenarios for Decarbonizing Japan. https://www.wwf.or.jp/activities/climate/cat1277/wwf_re100/#energyscenario2017 accessed 29 September 2017
[9] *ibid*

2.3 Case of Shimokawa-town

In the Shimokawa-town where is the northern part of Japan their energy self-sufficiency strategy is succeeding by using rich forestry industry. Shimokawa-Town presents the future vision which shows cash saving, creates jobs and happy forestry industry.

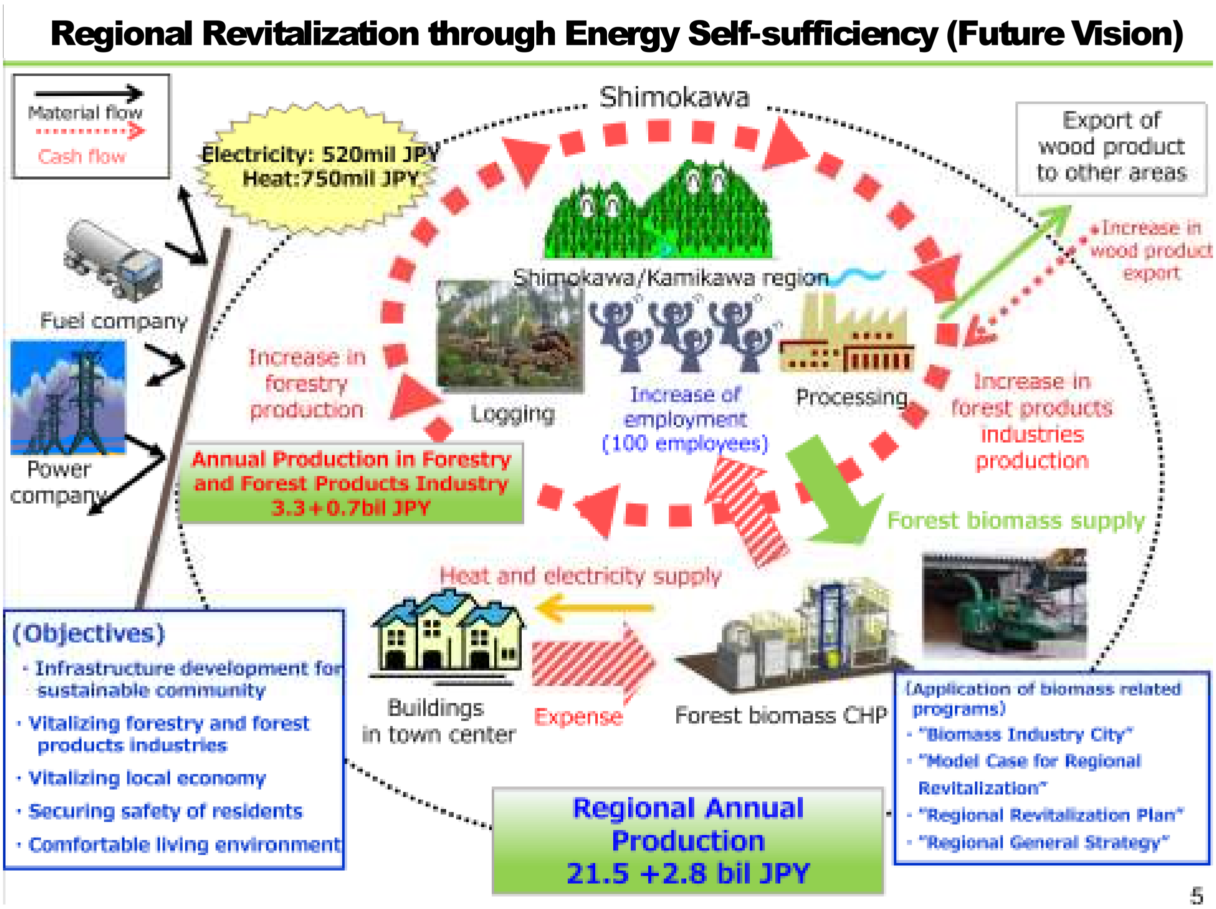


Fig. 2-3 Energy self-sufficiency success story in Shimokawa[10]

[10] Takahashi Y. (2015): Forest Biomass Energy Utilization in Shimokawa Town. https://www.toyotafound.or.jp/english/international/2015/activities/data/20151004_06YujiTakahashi.pdf accessed 13 July 2017

2.4 Japan renewable energy situation

Many renewable energy facilities have been installed after the Fukushima big earthquake. But the RE ratio has never been a high value both for the present situation and the target.
Recent RE share in Japan is about 10% and the target of it is 22-25%.

2.4.1 RE share and target

WWF Bridge Scenario reports that it will be possible to transform from all fossil fuel to RE and a half of fossil fuel will be decreased by energy saving and improving energy efficiency (Fig. 2-4).

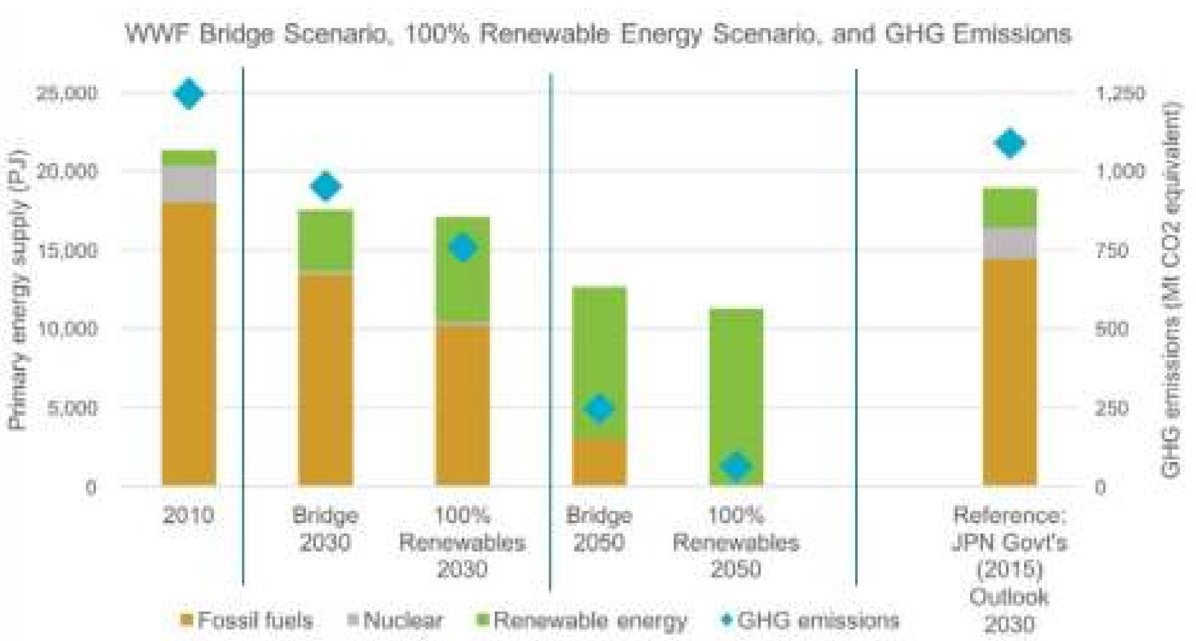


Fig.2-4 WWF Bridge Scenario, 100% Renewable Energy Scenario, And GHG Emissions[11]

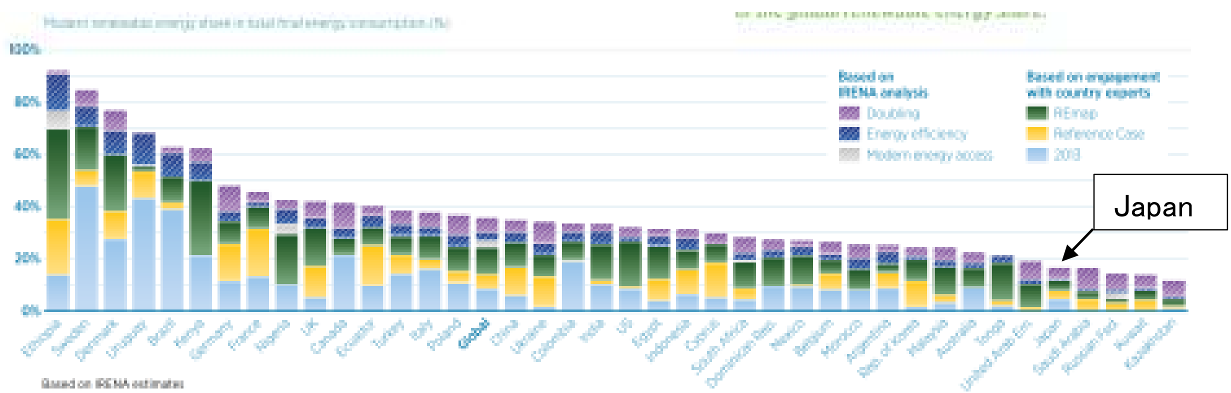


Fig. 2-5 Share of modern renewable in energy use of REmap countries, 2013-2030[12]

[11] Research Institute for Systems Technology (2017): Long-Term Scenarios for Decarbonizing Japan. https://www.wwf.or.jp/activities/climate/cat1277/wwf_re100/#energyscenario2017 accessed 29 September 2017
[12] Gielen D. et al: IRENA; REmap – 2016 – edition report:

Share of modern renewable energy use of Japan is under 20 percent (Fig. 2-5), it is very low level compare with another Remap countries.

2.4.2 Feed in tariff (FIT) in Japan

After the Fukushima big earthquake, Japan government is restarting to promote the renewable energy generator by FIT.
In this report the numbers of feed in tariff (FIT) in the Table 2-3 are applied.

Table 2-3 FIT in Japan, 2017-2019 [13]

		power generation capacity					
		<2MW		>2MW			
Lumber		price	period	price	period		
biomass		yen/kWh	year	yen/kWh	year		
		40	20	32	20		
		<10kW		10≦ <2,000kW		2,000kW<	
PV		yen/kWh	year	yen/kWh	yers	yen/kWh	yers
	2017	30					
	2018	28	10	21	20	auction	20
	2019	26					
		<0.2MW		0.2-1MW		1-30MW	
Hydro		yen/kWh	year	yen/kWh	year	yen/kWh	year
		25	20	21	20	15	20
about new FIT							
http://www.enecho.meti.go.jp/category/saving_and_new/saiene/kaitori/fit_kakaku.html							

http://www.irena.org/DocumentDownloads/Publications/IRENA_REmap_2016_edition_report.pdf accessed 2 May 2017

13 Agency for Natural Resources and Energy: http://www.enecho.meti.go.jp/category/saving_and_new/saiene/kaitori/fit_kakaku.html accessed 5 May 2017

3 Method of approach

3.1 Energy demand and potential date

In this chapter the target setting to 100% RE (except transportation and manufacturing sector) will be discussed. The major data sources used are:

- RE potential; “Study of Basic Zoning Information Concerning Renewable Energies (FY2012)”, Ministry of the Environment[14]
- energy consumption; “Energy consumption statistic data of each Prefecture “, Agency for Natural Resources and Energy[15]

Biomass and Small hydro power generation are first chosen because there are many rivers and forest in Japan and Biomass plants make new jobs. Next solar energy is better. As there are not so much flat and wide area in Japan, it will not be easy to construct wind farms. In this report RE for heating us mainly depending on the ground source heating pump (GSHP) system.

I assume that energy demand will be half of 2014, as the WWF report and Frankfurt’s energy concept. In this report fossil fuel means only converted oil.

3.2 GHG emission calculation

In the bioenergy system the carbon stocks in plants, but in the fossil energy system the carbon is emitted by carbon dioxide (Fig. 3-1).

The GHG emissions of RE and oil plants are adopted for generation in the Fig. 3-2 and for heating in the Fig. 3-3.

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[14] Ministry of the Environment (2012): Study of Basic Zoning Information Concerning Renewable Energies. www.env.go.jp/earth/report/h25-03/index.html - accessed 29 September 2017

[15] Agency for Natural Resources and Energy : Statistics of Energy Consumption in Tottori http://www.enecho.meti.go.jp/statistics/energy_consumption/ec002/results.html - accessed 20 September 2017

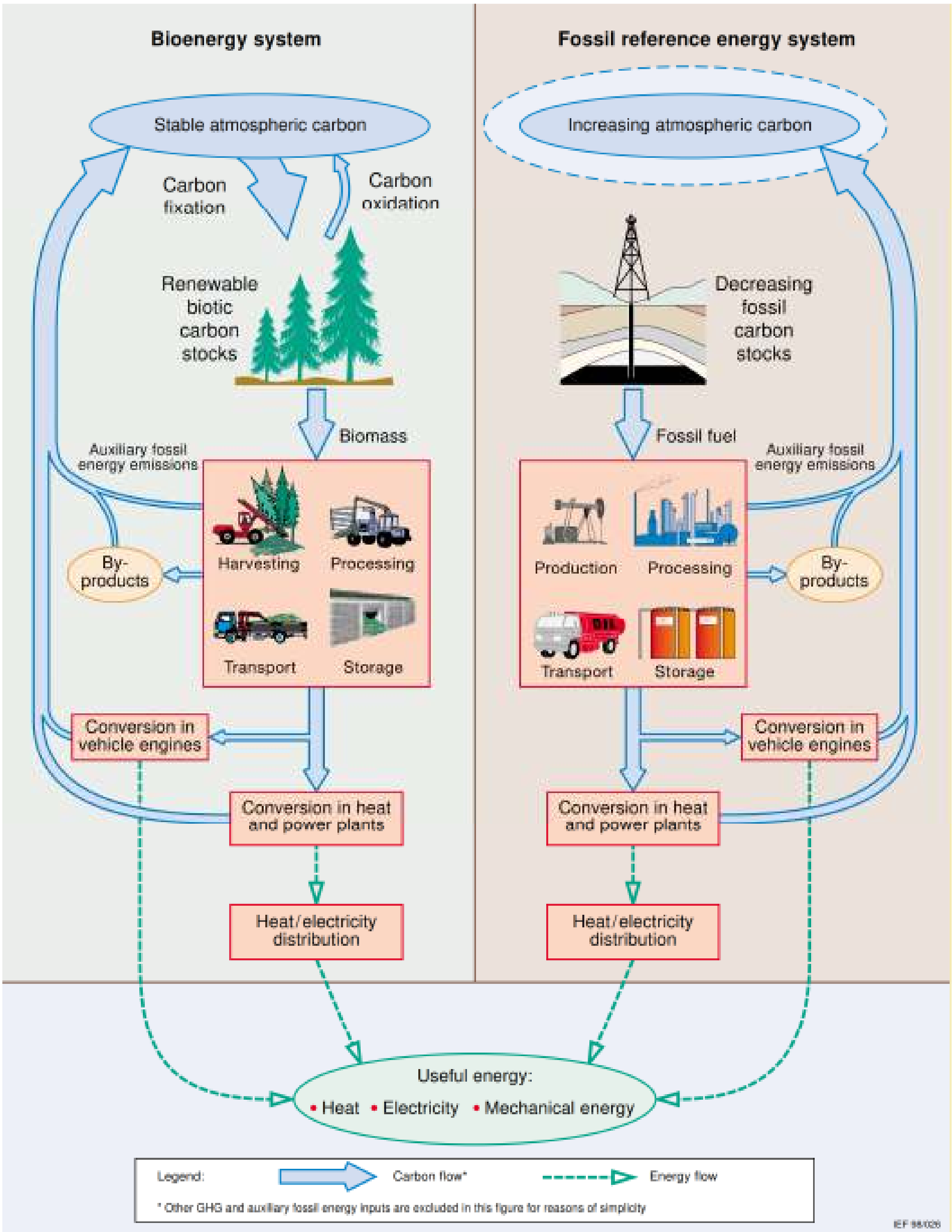

Fig. 3-1 Standard Methodology for calculation of GHG balances[16]

[16] IEA Bioenergy Task38 (2002): "Greenhouse Gas Balance of Biomass and Bioenergy Systems" https://www.forestry.gov.uk/pdf/IEA_GHG_gas_balances_of_biomass_systems_2002.pdf/$FILE/IEA_GHG_gas_balances_of_biomass_systems_2002.pdf - accessed 9 November 2017

GHG emission of biomass plant is very low, because carbon of timber is cycling like a Fig. 3-1.

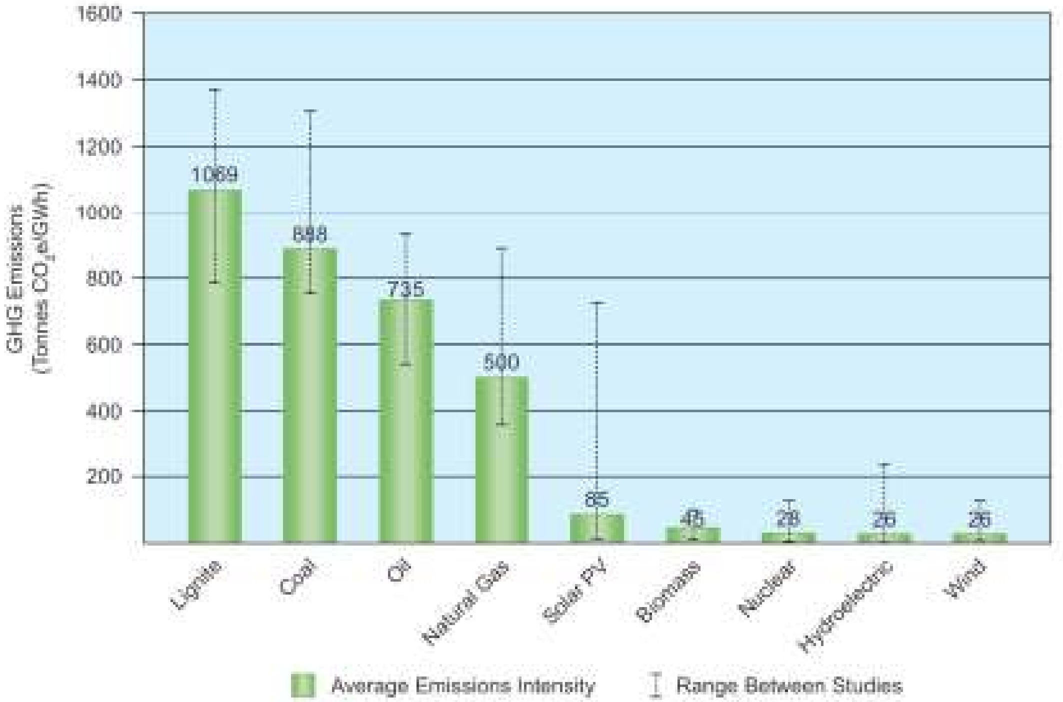

Fig. 3-2 Lifecycle GHG Emissions Intensity of Electricity Generation Methods[17]

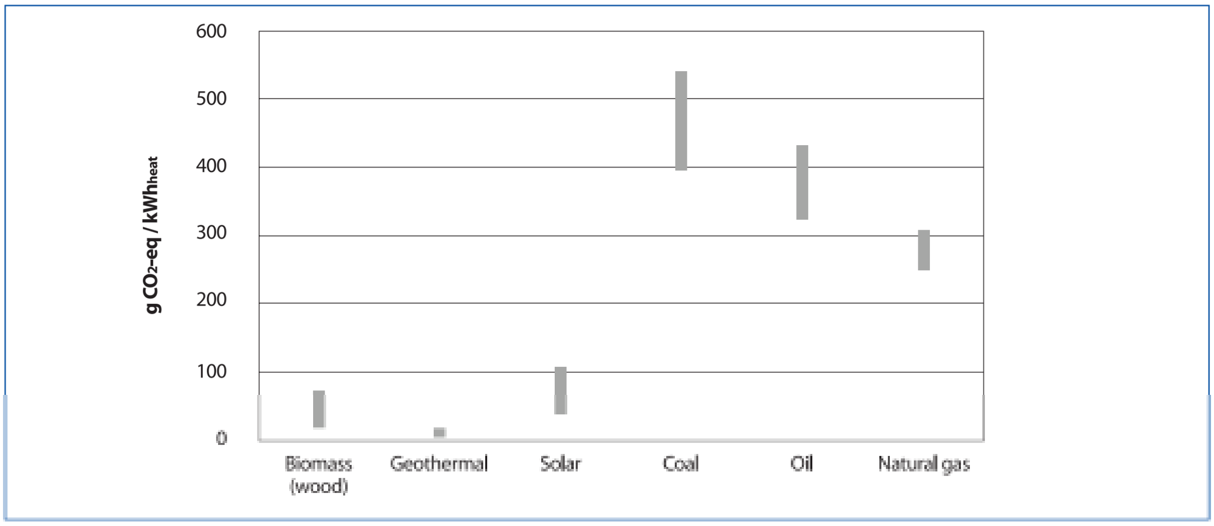

Figure 3. Ranges of GHG emissions for heat supply from different sources. Source: Cherubini *et al.* 2009. Energy- and GHG-based LCA of biofuel and bioenergy systems: Key issues, ranges and recommendations. *Resources, Conservation and Recycling, 53: 434-447.*

Fig. 3-3 Rangers of GHG Emissions for heat supply from different sources.[18]

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[17] WNA Report (2011) : Comparison of Lifecycle Greenhouse Gas Emissions of Various Electricity Generation Sources, http://www.world-nuclear.org/uploadedFiles/org/WNA/Publications/Working_Group_Reports/comparison_of_lifecycle.pdf - accessed 28 August 2016

[18] Bird N. et al. IEA Bioenergy: Using a Life Cycle Assessment Approach to Estimate the Net Greenhouse Gas Emissions of Bioenergy, http://www.ieabioenergy.com/wp-content/uploads/2013/10/Using-a-LCA-approach-to-estimate-the-net-GHG-emissions-of-bioenergy.pdf - accessed 27 September 2017

4 Case study: How to proceed the transition from fossil to renewable energy in Tottori Prefecture in Japan

4.1 Tottori General information

4.1.1 Location

In Japan the population is decreasing and the manufacturing industry is flowing out to abroad. The middle-income hierarchy is decreasing now. I chose the Tottori Prefecture where is west local area in Japan. Tottori-Prefecture is my hometown and has the smallest population in Japan. The population is decreasing and the aged increasing every year. It is one of the typical local area in Japan.

Population; 573,441(2014)
Total area; 3,507km2

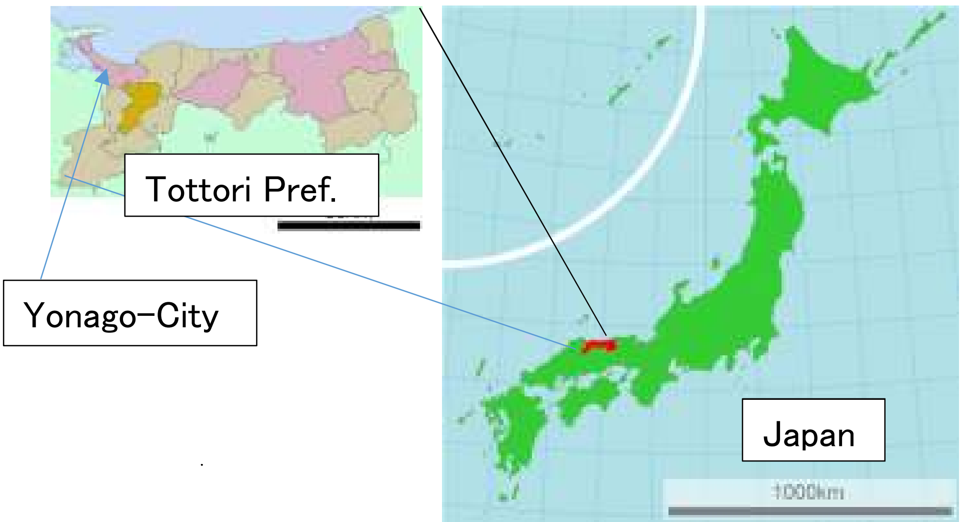

Fig.4-1 Tottori location in Japan[19]

[19] Tottori Prefecture, https://en.wikipedia.org/wiki/ Tottori – accessed 29 April 2016

4.1.2 Weather

In this region, it is snow in winter, it is rainy season at the end of spring and the typhoon comes in autumn. The temperature is over 30℃ in summer and is a little bit below zero in winter.
One weather sample is shown Fig. 4-2. Yonago is central city in Tottori west area.

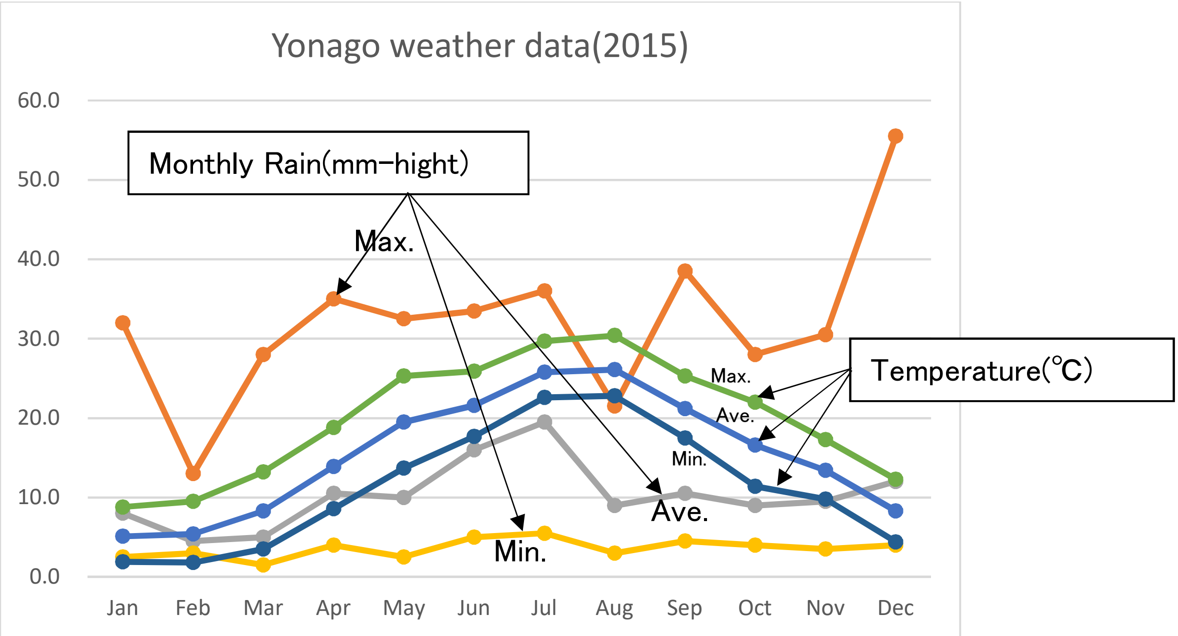

Fig. 4-2 Yonago weather data [20]

[20] the Japan Meteorological Agency, data base Yonago (2015) : http://www.data.jma.go.jp/obd/stats/etrn/view/monthly_s1.php?prec_no=69&block_no=47744&year=2015&month=&day=&view=p1 – accessed 22 April 2016

4.1.3 Energy Situation

RE share of electricity in Japan is 10.7% and one in Tottori is 31%.

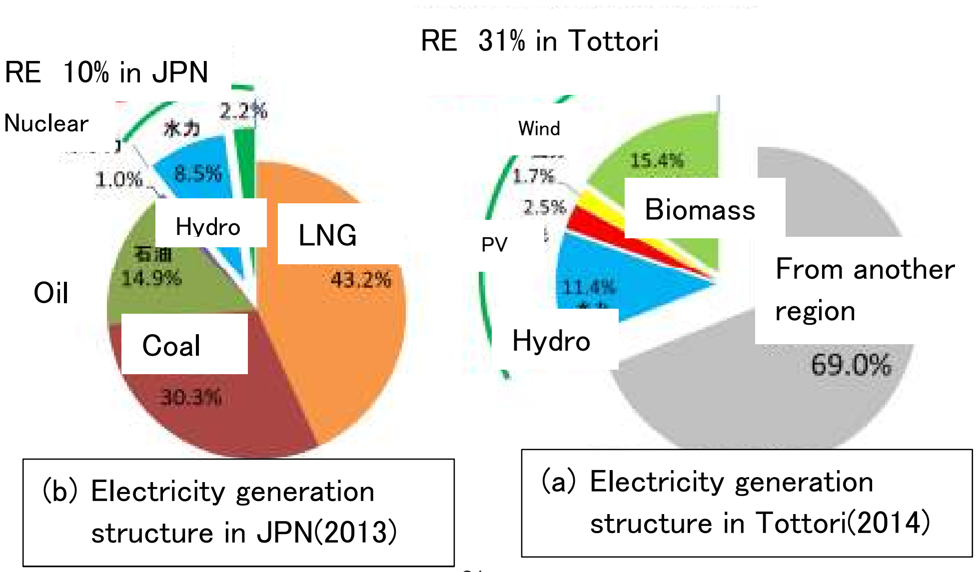

Fig. 4-3 RE share of electricity [21]

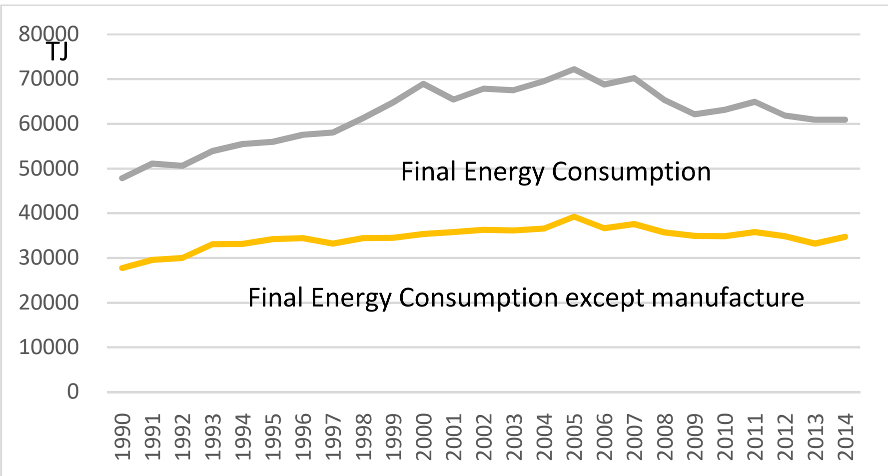

Fig. 4-4 Final Energy Consumption in Tottori

energy consumption; "Energy consumption statistic data of each Prefecture ", Agency for Natural Resources and Energy [22]

As the population and GDP in Tottori are decreasing in recent ten years, final energy consumption is also decreasing. But the final energy consumption except manufacture is same level in recent ten years.

RE supplier are increasing but the share is only 16.3% (Table 4-1).

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[21] Tottori Government, Next Energy Park in Tottori (2015): http://www.pref.tottori.lg.jp/secure/850271/enepa_tottori.pdf - accessed 12 May 2017

[22] Agency for Natural Resources and Energy : Statistics of Energy Consumption in Tottori http://www.enecho.meti.go.jp/statistics/energy_consumption/ec002/results.html - accessed 20 September 2017

Table 4-1 RE supply in Tottori (2016) [23]

		TJ/y	GWh/y
Elec.	PV	1,807	502
	Wind	696	193
	Geothermal	1	0
	SHP	2,271	631
	Biomass	448	124
Elec. Sum		5,223	1,451
Heating	Solar	256	71
	Geothermal	275	76
	Biomass	43	12
Heating sum		574	159
Total		5,797	1,610
Itakura(Chiba-Uni) sustainable region2016			
RE ratio		16.3%	

Except transformation and manufacturing

4.1.4 Local government RE Target in Tottori

The 920MW RE facilities will be invested by the end of 2018 by accelerating the introduction of facilities utilizing a profit in the renewable energy which is imminent while considering influence on scene and ecosystem

Table 4-2 RE investment target [24] (kW)

Main target	Base data (2014)	Target (2018)
Mega PV (>10kW)	91,617	151,000
House PV (<10kW)	39,937	50,000
Mega Wind	59,100	59,200
Biomass(Elec. & Heating)	492,068	541,500
Hydro	117,748	118,300
Total	800,470	920,000

[23] Kurasaka H. (2016): Sustainable Zone 2016, http://sustainable-zone.org/wordpress/wp-content/uploads/sustainablezone-2016FY-report.pdf - accessed 18 May 2017

[24] Tottori Government (2016): Tottori Initiative Plan 2: http://www.pref.tottori.lg.jp/secure/1015875/InitiativePlan.pdf - accessed 29 August 2017

4.1.5 Current RE situation in Tottori

・As for the PV power generation for business, domestic eminent mega solar power station is introduced into the Sakitsu, Yonago-City district, and 58 places, 91,617kW are introduced as of the end of 2014.

・ 39,937kW is introduced into (less than 10kW) small home photovoltaic power generation facilities at the end of 2014. These facilities increased to approximately 8 times in three years from the end of 2010.

・As for the 41 Mega wind farms (59,100kW) are set up as of the end of 2014. All the facilities were installed in the land, and all were introduced before 2007.

・As for the biomass the heat utilization by a power station or the papermaker of only wood chips are performed. In addition, a heat utilization-centered action is carried out in public accommodation or the establishment of the wood industry.

・The small hydropower generation plants have been formerly installed in the mountain areas and decrepit facilities in the plants are renewed.

But Tottori government have no plan to proceed to 100% RE.

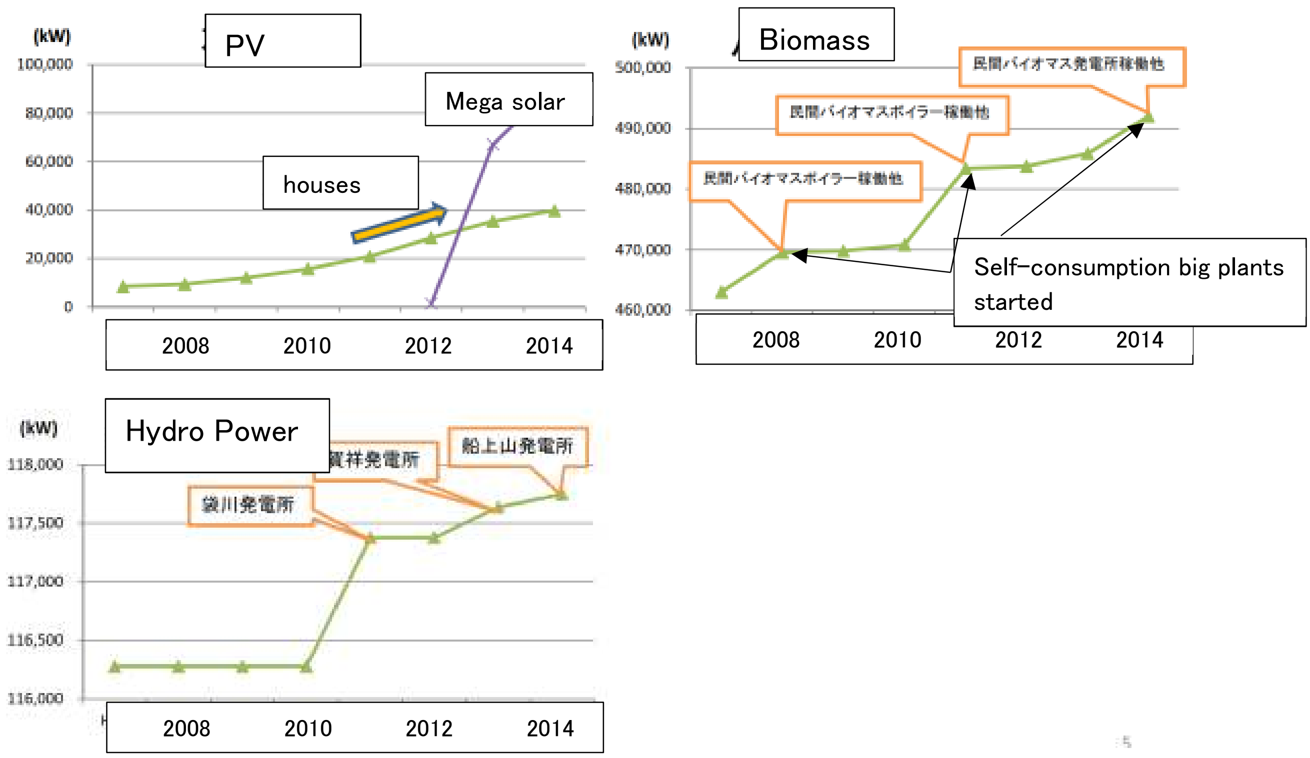


Fig. 4-5 RE (PV, Biomass and Hydro generation) trend in Tottori [25]
(Biomass data include self-sufficient industrial plants. In this report these manufacturer data are excepted)

[25] Tottori Government (2016): Tottori Initiative Plan 2: http://www.pref.tottori.lg.jp/secure/1015875/InitiativePlan.pdf - accessed 29 August 2017

4.2 100% RE target policy in Tottori

The transition policies from fossil to renewable energy are following points.

1）Energy efficiency increasing and energy saving (less 50%, Energy consumption)
2）Switch from fossil fuel to renewable by mainly SHP, Biomass, GSHP and PV
3）Basically energy self-sufficient areas are divided into three lands along with big rivers

East area; Sendai river --- Central city is the Tottori-City
Middle area; Tenjin river --- Central city is the Kurayoshi-City
West area; Hino river --- Central city is the Yonago-City

There are many mountains in the southern area in Tottori, many rivers and rich forest. There is much wind energy in Tottori especially in winter, but mountain and forest areas covered 74%. Many people live in flatland. Limited areas are suitable for the wind turbines. In this report no wind farm was considered.

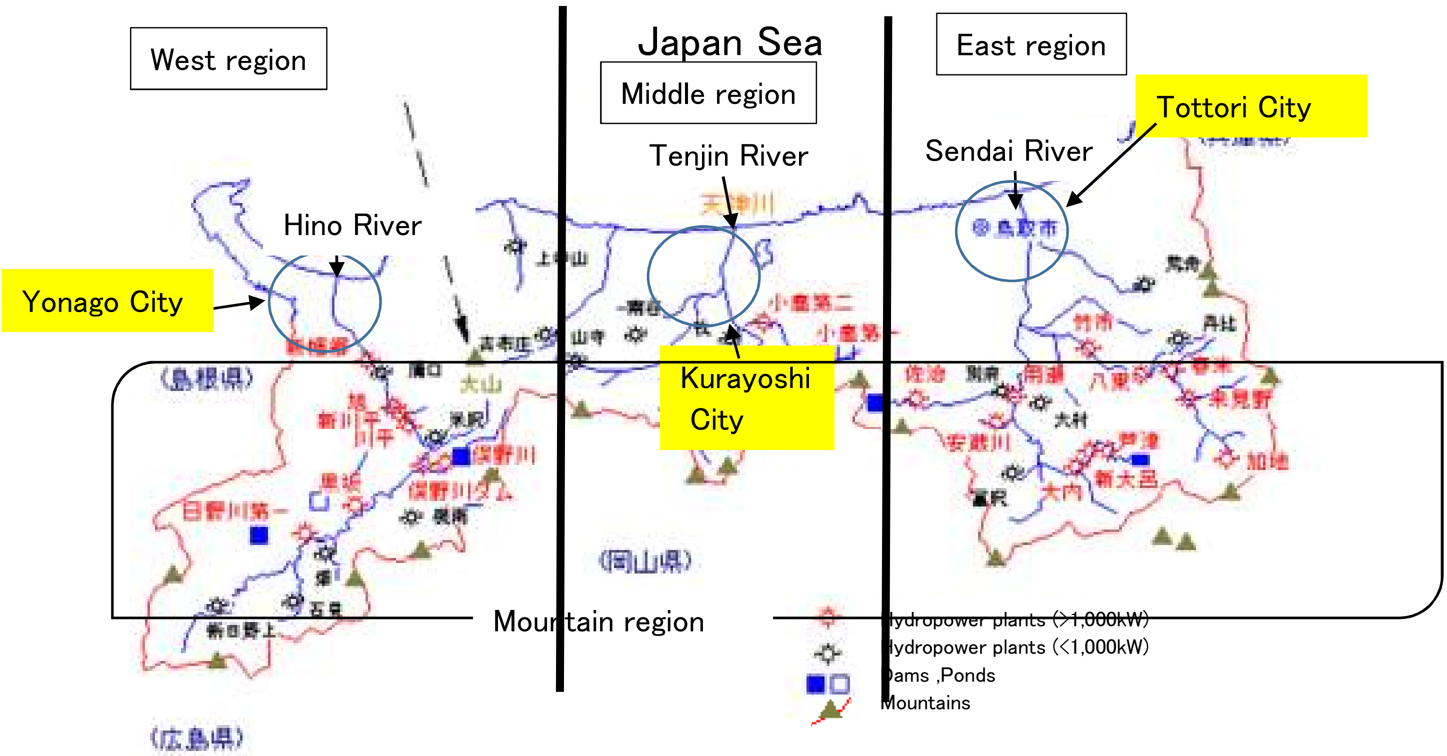


Fig.4-6 West, middle and East area in Tottori[26]

[26] Hydro Power Plant Map in Tottori: http://www.geocities.jp/shuji_maru/tottori/map/01.htm - accessed 24 August 2016

Tottori-Prfecture is divided three regions. They are east, middle and west region. From the data of prefecture energy consumption data, I calculated the energy demand of each regions.

"Energy consumption statistic data of each Prefecture ", Agency for Natural Resources and Energy,

Table 4-3 Each Region Energy Demand in Tottori (2014) [27]

		Population(2015)	Heating	Electricity	Heating*	Electricity*
					20,694	14,009
			GWh		TJ	
E	Tottori-City	193,717	1,942	1,315	6,991	4,732
E	Iwami-Town	11,485	115	78	414	281
E	Wakasa-T	3,269	33	22	118	80
E	Chizu-T	7,154	72	49	258	175
E	Yazu-T	16,985	170	115	613	415
East	subtotal	232,610	2,332	1,579	8,394	5,683
M	Kurayoshi-C	49,044	492	333	1,770	1,198
M	Misasa-T	6,490	65	44	234	159
M	Yurihama-T	16,550	166	112	597	404
M	Kotoura-T	17,416	175	118	628	425
M	Hokuei-T	14,820	149	101	535	362
Middle	subtotal	104,320	1,046	708	3,765	2,549
W	Yonago-C	149,313	1,497	1,013	5,388	3,648
W	Houki-T	11,118	111	75	401	272
W	Nichinan-T	4,765	48	32	172	116
W	Hino-T	3,278	33	22	118	80
W	Sakaiminato-C	34,174	343	232	1,233	835
W	Hiezu-Village	3,439	34	23	124	84
W	Daisen-T	16,470	165	112	594	402
W	Nanbu-T	10,950	110	74	395	268
W	Koufu-T	3,004	30	20	108	73
West	subtotal	236,511	2,371	1,605	8,535	5,778
	Total	573,441	5,749	3,892	20,694	14,009
* :	Total Energy Consumption except manufacturing & Transportation in Tottori (2014)					
http://www.enecho.meti.go.jp/statistics/energy_consumption/ec002/results.html#headline2						

Ministry of Economic, Trade and Industry (Meti) collects energy demand statistics data in every prefecture every year. Table 4-3 shows the heating and electricity demand data on each region which is divided the total number by region population ratio.

[27] Agency for Natural Resources and Energy: Statistics of Energy Consumption in Tottori http://www.enecho.meti.go.jp/statistics/energy_consumption/ec002/results.html - accessed 20 September 2017

Table 4-4 RE potential in Tottori [28]

(GWh/y)	Electricity			Heating		Total
	PV	Wind	SHP	Solar	Ground	
East	727	573	230	344	2,607	4,481
Middle	401	230	54	204	1,301	2,190
West	684	496	108	366	2,578	4,231
total	1,812	1,299	392	914	6,486	10,902

Energy demand target in 2050 is half value of current (2014) demand.

I will study precisely RE supply in Tottori west region (Table 4-5, 4-6).

Table 4-5 Tottori RE target in 2050

Table Tottori RE Target 2050 (2014 base)

		Electricity					Heating				Total
		PV	Wind	SHP	Biomass	Total	Solar	Ground	Biomass	Total	
East	GWh/y	531	10	230	19	789	172	981	13	1,166	1,955
Middle	GWh/y	293	0	54	8	354	102	415	6	523	877
West	GWh/y	523	152	108	19	803	183	990	13	1,186	1,988
Total						1,946				2,874	4,820

Table 4-6 Tottori west region RE sources target in 2050

		Electricity							Heating				Total
		PV house	PV public	PV Sum	Wind	SHP	Biomss	Total	Solar	Ground	Biomass	Total	
Capacity	MW	341	132	474	100	24	3	598	138	251	12		
Energy production	GWh/y	377	146	523	152	108	19	803	194	976	13	1,183	1,986

Biomass plant capacity is calculated by the maximum amount of woody fuel supply in the prefecture. Small hydro plant capacity is as same as potential. Solar energy which means PV and solar heating is calculated by 50-80% of potential. Wind capacity is calculated from the total demand minus another RE capacities. Wind capacity is nearly equal to the current wind capacity. It means wind farm will not be constructed.

[28] Ministry of the Environment (2012): Study of Basic Zoning Information Concerning Renewable Energies. www.env.go.jp/earth/report/h25-03/index.html - accessed 29 September 2017

4.3 **Energy efficiency**

4.3.1 Home energy usage trend [29]

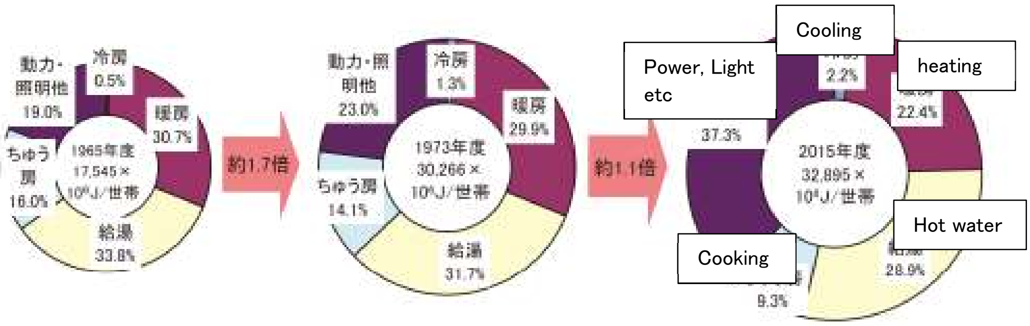
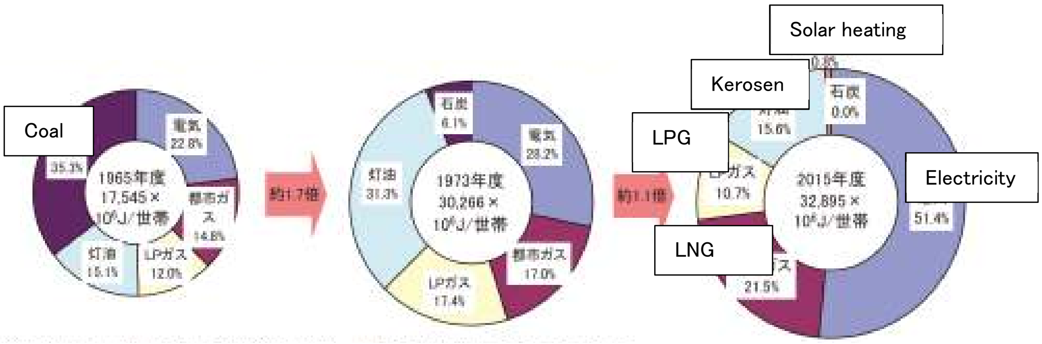


Fig. 4-7 Home energy consumption purpose of energy



17,454*10^6 Joule/home (1965) 30,266*10^6 Joule/home (1973) 32,285*10^6 Joule/home (2015)

Fig. 4-8 Home energy consumption energy resource

Home energy consumption in 2015 is about two times in2015.

Energy strategy in Frankfurt and WWF scenarios show that it is possible to decrease a half energy consumption by changing to high energy efficiency elecrto-devices, promote ZEH and reducing standby energy consumption (Fig.2-2, Table 2-2).

[29] Agency for Natural Resources and Energy (2017) : Whitepaper 2017, http://www.enecho.meti.go.jp/about/whitepaper/2017pdf/whitepaper2017pdf_2_1.pdf - accessed 23 September 2017

4.4 **Biomass**

The suitable biomass plant scale, type and number are selected for this region.

4.4.1 Biomass plant scale

4.4.1.1 Suitable biomass plant scale for fuel supply

How many biomass electricity generation plants will be construct for the fuel supply point of view?
Big scale biomass combined heat and power (CHP) plat is better than small one, as the energy efficiency is high and construction cost is low per generation output unit. But the big plant needs much biomass fuel and then getting fuel competition rises in price. In this report I think the biomass plant scale is the best for woody fuel self-sufficient in the area.

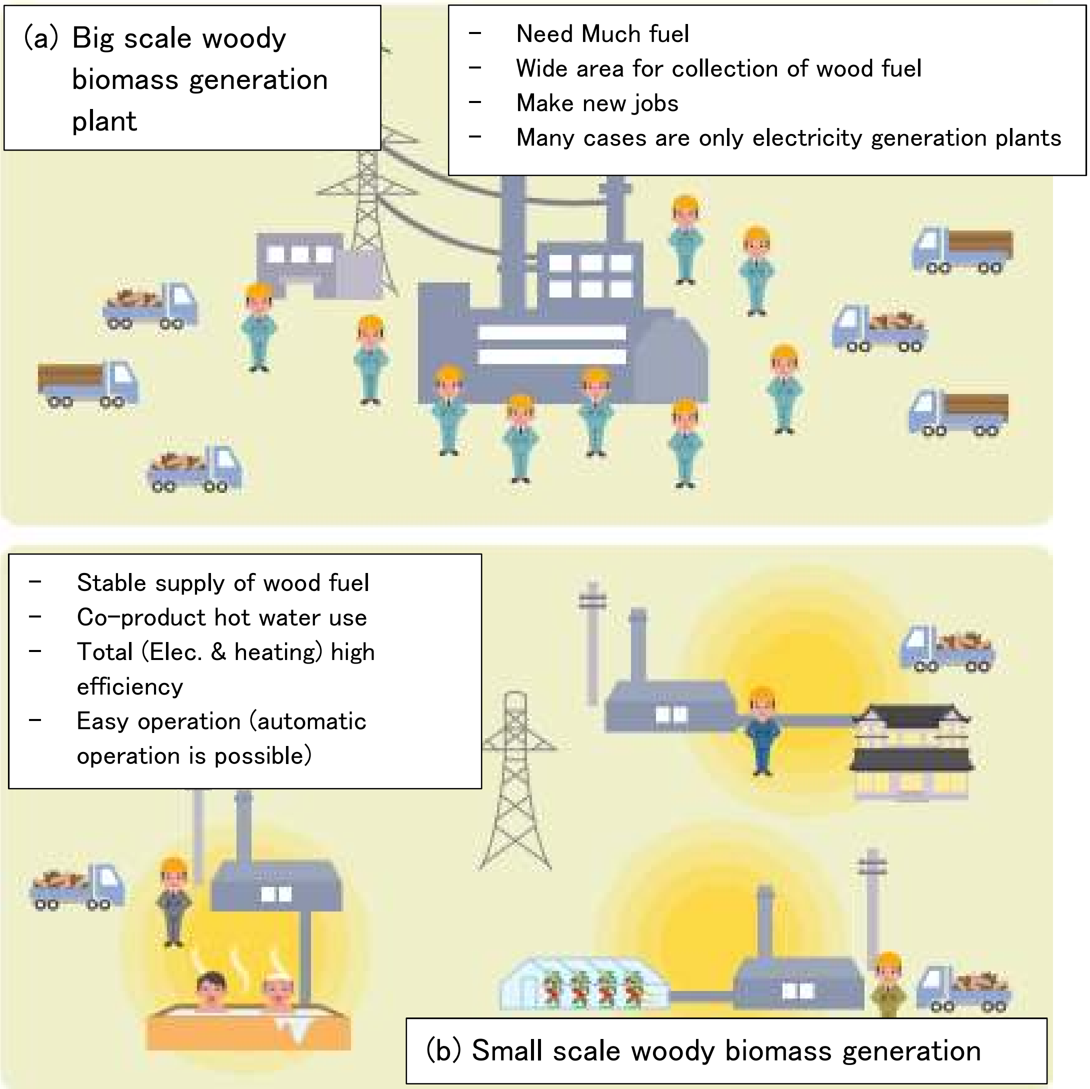


Fig. 4-9 Comparison with biomass big vs small scale plant [30]

[30] Japan Woody Bioenergy Association (2015): Small Scale Woody Biomass Generation Introduction Guide, https://www.jwba.or.jp/small-woody-biomass-generation-guidebook/ - accessed 30 September 2017

4.4.1.2 The amount of wood supply for fuel

Fig. 4-10 shows wood production trend in Tottori. From 2000 to 2014 the wood production is about 200×10^3 m^3 .

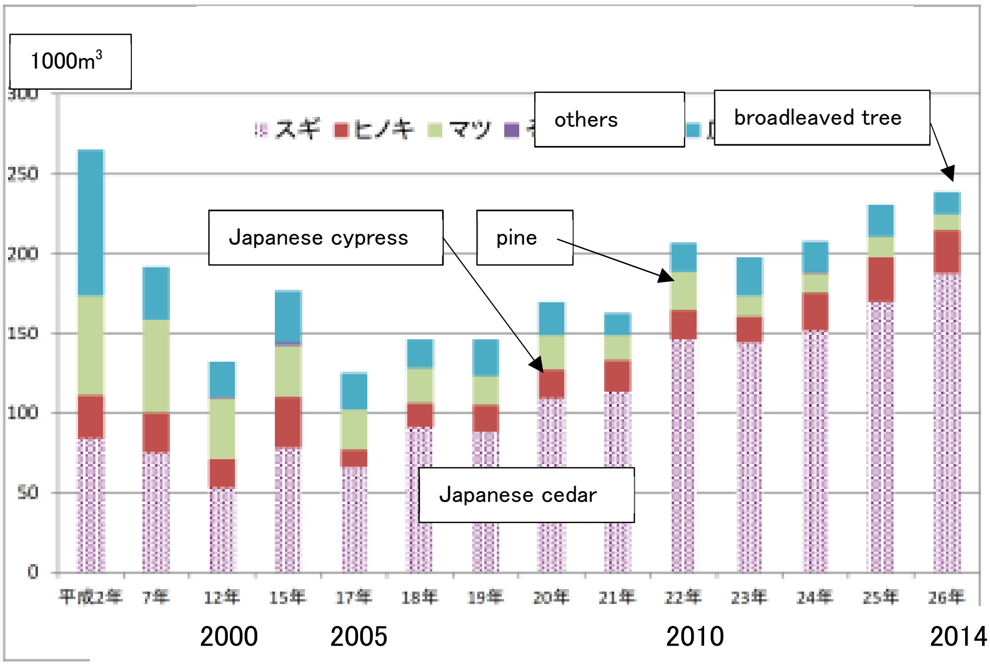


Fig. 4-10 Wood production trend in Tottori [31]

The density of Japanese cedar is about 0.4t-dry/m3. 20% part of a timber is usually used for energy (Fig. 4-11).

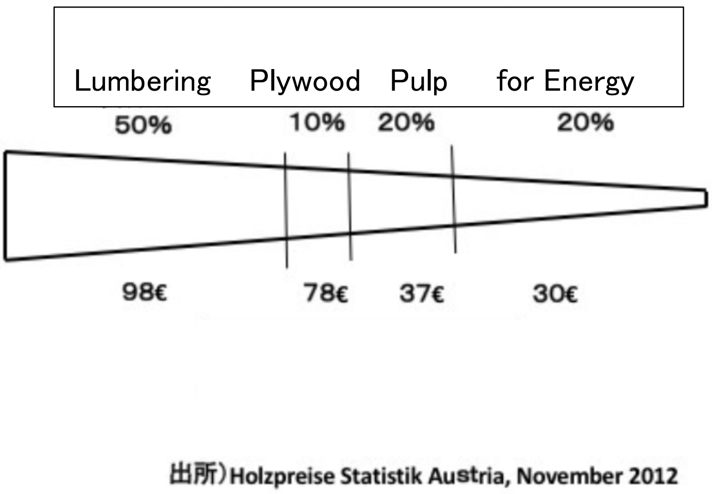


Fig. 4-11　Volume ration a Conifer for uses [32]

[31] Tottori Government Wood Industry Statistics (2016): General forestry conditions in Tottori http://www.pref.tottori.lg.jp/secure/1027087/1-ringaikyou.pdf - accessed 3 July 2017

[32] Japan Woody Bioenergy Association (2015): Redefinition of Unused Timber, https://www.jwba.or.jp/report/miriyouzai/ - accessed 12 September 2017

The amount of wood for energy in Tottori are about 20kt-dry/year.

$$200 \times 10^{3} (m^3/year) \times (20/80) \times 0.4 \quad = \quad 20,000 \text{t-dry/year}$$

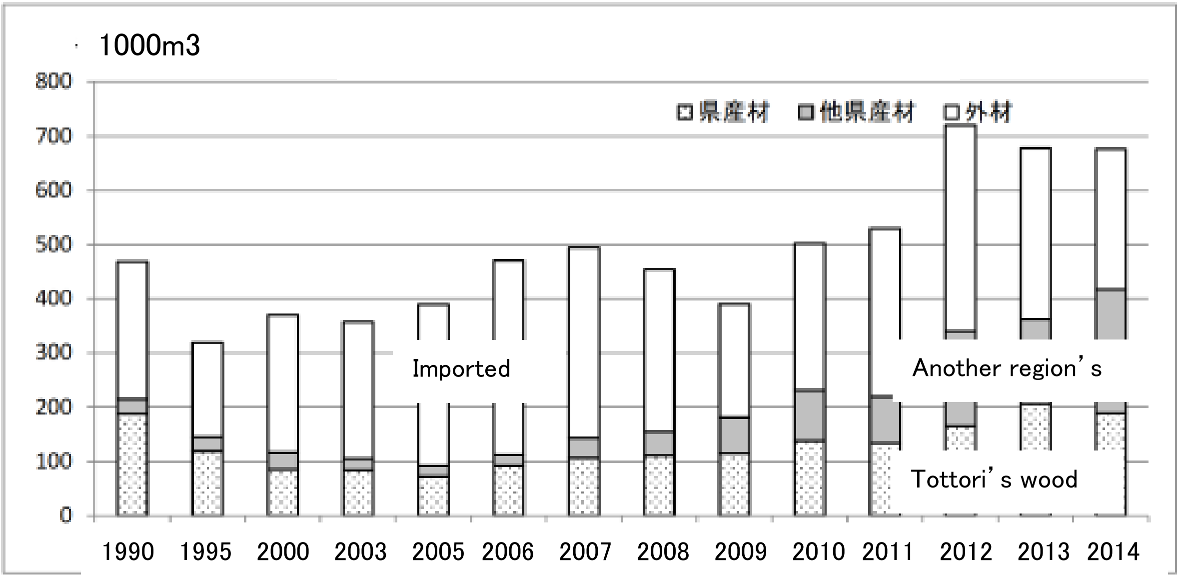


Fig. 4-12 Wood demand trend in Tottori [33]

In this report I suppose that all wood consumed in Tottori will be switched from another and imported wood to own one. 80,000t-dry waste wood will be got.

$$800 \times 10^{3} (m^3/year) \times (20./80) \times 0.4(t/m^3) = 80,000 \text{ t-dry/year}$$

[33] Tottori Government Wood Industry Statistics (2016): General forestry conditions in Tottori http://www.pref.tottori.lg.jp/secure/1027087/1-ringaikyou.pdf - accessed 3 July 2017

4.4.1.3 Biomass plant type

In this report the model combined heat and power (CHP) biomass plant is chosen.[34]

Table 4-7 Biomass CHP Model Plant Spec:

Plant type; small woody biomass CHP plant (Organic Rankine Cycle; ORC type)
Capacity; 1000kW$_{el}$, Output 985kW$_{el}$, self-consumption 223kW$_{el}$
4000kW$_{th}$, Output 4081kW$_{th}$
Sales amount of Elec. & hot water per year; 6,033MW$_{el}$h, 21,009MW$_{th}$h
Total fuel consumption:20491t/year (50%wet chip)

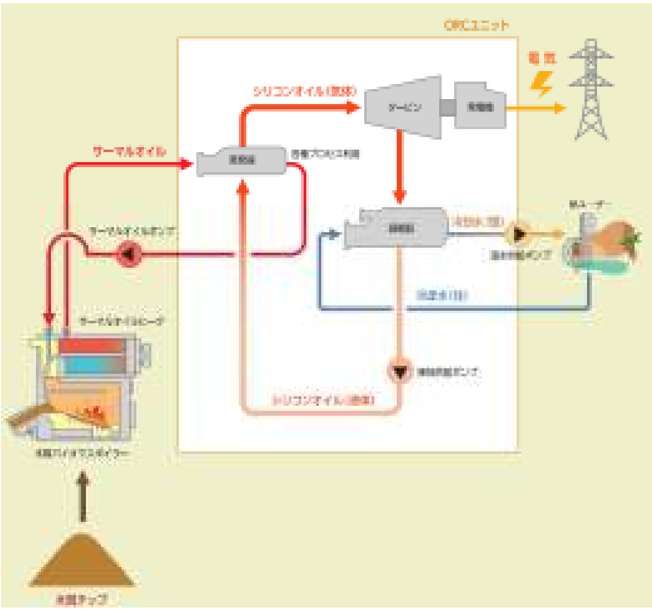


Fig. 4-13 small woody biomass ORC turbine system case [35]

[34] Japan Woody Bioenergy Association (2015): Small Scale Woody Biomass Generation Introduction Guide, https://www.jwba.or.jp/small-woody-biomass-generation-guidebook/ - accessed 30 September 2017
[35] *Ibid.*

By the fuel supply point of view, the maximum CHP plant number is about eight.
3 plants will be constructed in West and East region each. 2 plants in Middle.

Table 4-8 Plant number for each region

Region	Population	Tree planting area	Plant number
	1,000 persons	ha	
East	233	5,296	3
Middle	104	4,524	2
West	237	5,340	3

4.4.2 Ecological points of biomass plant installations

GHG reduction of switching from oil to biomass electricity generation plants in Tottori west region is calculated.

Table 4-9 GHG reduction of Biomass plants installations

				reduction
		Biomass	Oil	GHG
GHG Emissions Intensity of Elec. Generation	t-CO2 e/GWh	45	735	
	t-CO2 /year	854	13,945	13,091

4.4.3 Economic points of biomass plant installations

Table 4–10 shows biomass CHP plants installation and O&M costs in Tottori west.

Table 4-10 Biomass plant(s) Investment and O&M cost

			Biomass	
	plant number		1	3
	capacity	kW	1,000	3,000
	Energy output	MWh/y	4,230.1	12,690
	Inv. Cost	EUR	10,000,000	30,000,000
	O&M	EUR/year	138,004	414,012
01-10year	Elec. Sale	EUR/year	1,402,121	4,206,364
11-20year	Elec. Sale	EUR/year	1,402,121	4,206,364

Table 4-11 Oil reduction by Biomass plant(s) installation

			Biomass	
	plant number		1	3
	capacity	kW	1,000	3,000
	Energy output	MWh/y	4,230.1	12,690
	Oil Reduction	kL/year	960.2	2,880.7
	Oil Red. Cost(now)	EUR/year	446,875	1,340,624
	Oil Red. Cost(high)	EUR/year	795,511	2,386,532
Oil cost(now 2017); 60.5yen/L(0.465€/L)、				
Oil cost (high 2008); 107.7(0.828)				130yen/€

4.5 **Solar Energy Technologies for Electricity and Heating**

4.5.1 PV installations for electricity in Tottori west

4.5.1.1 PV panel selection

PV panels will install to personal houses and public buildings. The capacity of the panels are 3.6kW for personal and 500kW for public. I discuss and calculate from the data of NEDO, Module 3 and the Kyocera web site. Kyocera is one of the major PV manufacture and sales company in Japan.

PV cells are generally made either from crystalline silicon or thin film. Current PV Cell Efficiencies (Laboratory Values) shows Fig. 4-14

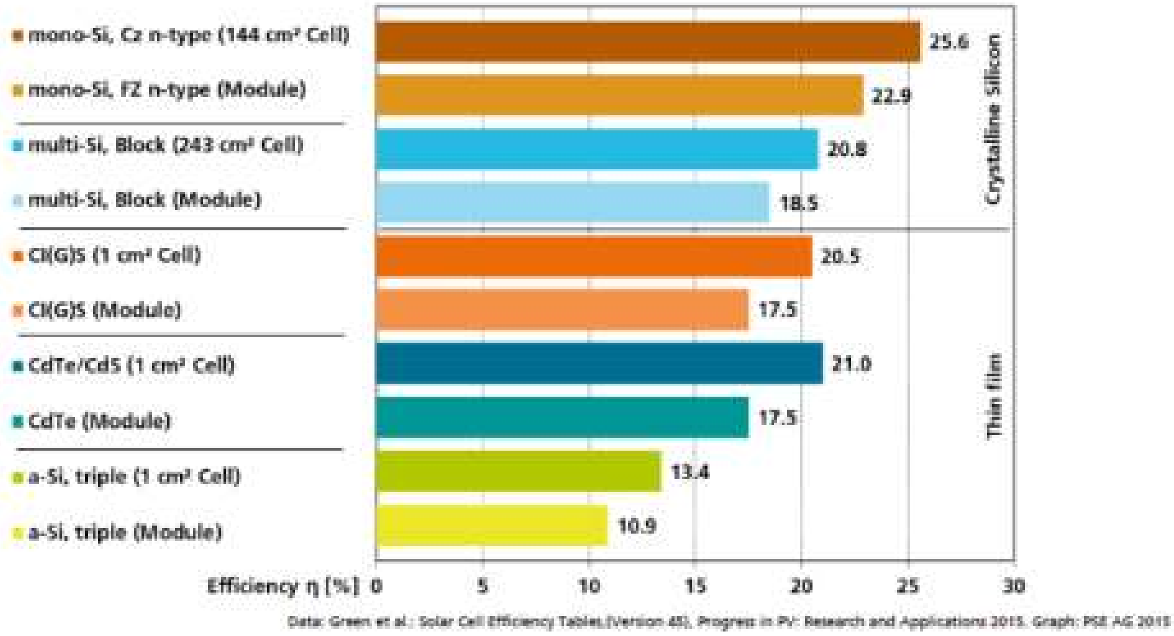


Fig. 4-14 Solar cell efficiencies as of 2015 (laboratory values) [36]

Table 4-12 World PV Module Production (2014E): Percentage Share Breakdown of Production Volume by Technology [37]

Technology	% Share
Crystalline Silicon	88.2
Monocrystalline Silicon (Mono c-Si)	22.8
Multicrystalline Silicon (Multi c-Si)	65.4
Thin-Film	11.8
Cadmium Telluride (CdTe)	4.9
Copper Indium Gallium Selenide (CIGS)	4.0
Amorphous Silicon (a-Si)	2.9
Total	100.0

In this report multicrystalline silicon is selected, because it is cost effective and the first production volume in the world.

[36] Fechner, H. (2016): "Photovoltaic" p. 9, MSc Program – Module 3, Renewable Energy in Central and Eastern Europe

[37] Fechner, H. (2016): "Photovoltaic" p. 13, MSc Program – Module 3, Renewable Energy in Central and Eastern Europe

4.5.1.2 Number of PV installations

We will invest 70% of PV potential in Tottori. The PV generation value of houses is 341MW and of public buildings is 132MW.

Table 4-13 Electricity target (2050) in west region

	Electricity		
	PV house	PV public	PV Sum
MW	341	132	474
GWh/y	377	146	523

In this section, the Kyocera PV panel (KJ220P-3MD4GC) is selected. Its spec is following.

Maximum output: 220W, Module efficiency: 16.6%,
External appearance: W1,338*L990*H46mm

Table 4-14 PV panel number, total output and total PV area

	Panel number	Total output	Total PV area
3.6kW:	18panels	220*18W	(1.338*0.99)*18m2
500kW:	2,273panels	220*2,273W	(1.338*0.99)*2,273m2

4.5.1.3 Solar irradiation in Yonago

A representative location where I choose is Yonago.

Monthly solar irradiation time and energy shows following table and figure.

Table 4-15 Solar Irradiation in Yonago (2015)

	Time/hr	day/m	MJ/m2/d	kWh/m2/d	kWh/m2/M
Jan	57.3	31	7.2	2.00	62
Feb	75.8	28	10.6	2.94	82
Mar	168.2	31	13.4	3.72	115
Apr	183.4	30	19.1	5.31	159
May	253.5	31	21.6	6.00	186
Jun	159.3	30	18.2	5.06	152
Jul	135.8	31	14.3	3.97	123
Aug	188.4	31	21.3	5.92	183
Sep	142.4	30	15.4	4.28	128
Oct	216.8	31	13.5	3.75	116
Nov	88.2	30	9.1	2.53	76
Dec	79.4	31	5.9	1.64	51
sum (kWh/m2/year)					1434
Average			14.13	3.93	

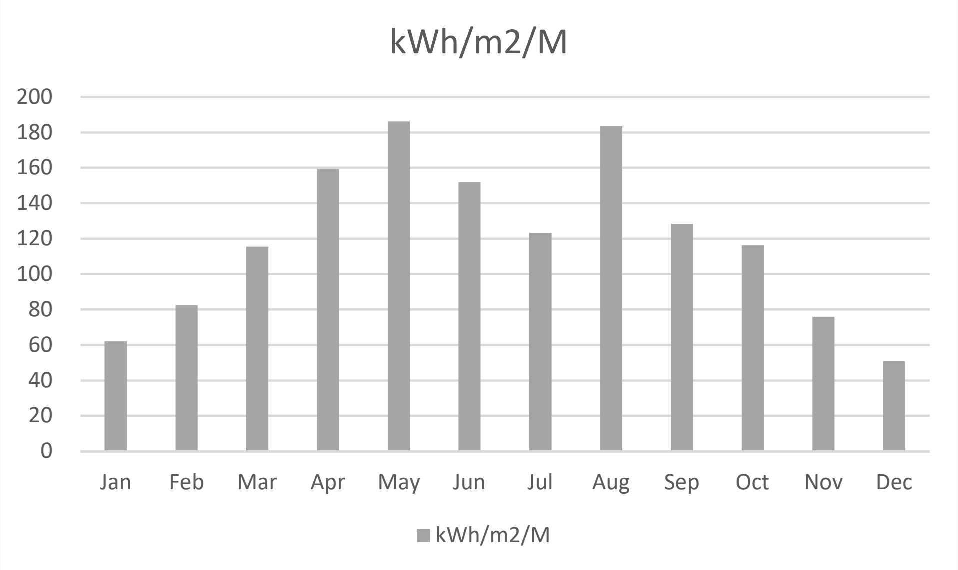


Fig.4-15 Monthly solar irradiation in Yonago (2007) [38]

[38] Japan Meteorology Agency data; http://www.data.jma.go.jp/obd/stats/etrn/view/monthly_s1.php?prec_no=69&block_no=47744&year=2015&month=&day=&view=p1 accessed 21 April 2016

4.5.1.4 Ecological appraisal of the PV installations

According to Fig. 3-2 GHG reduction of PV is calculated and the results are shown in Table 4-16.

Table 4-16 Tottori west region GHG reduction for PV electricity supply

		PV	Oil	GHG reduction
GHG Emissions Intensity of Elec. Generation	t-CO2 e/GWh	85	735	
	t-CO2 /year	44,477	384,593	340,117

4.5.1.5 Economic appraisal of the PV installations

Table 4-17 PV Investment Cost in Japan [39]

		1€=	130	yen
	1,000yen/kW		€/kW	
	10-50kW	50-500kW	10-50kW	50-500kW
2012	430	372	3,308	2,862
2013	383	341	2,946	2,623
2014	346	323	2,662	2,485
2015	325	309	2,500	2,377
2016	327	300	2,515	2,308

[39] Ministry of Economy Trade and Industry (2016): Opinions on the procurement price after 2016, www.meti.go.jp/committee/chotatsu_kakaku/pdf/028_01_00.pdf - accessed 28 September 2017

According to these value, I calculated investment and O&M costs of PV installation. By these constructions the reduction of quantity and costs of oil consumption is shown in figure 4-18, 4-19. Oil reduction costs is calculated by two cases. One is high in 2008, other is current price in 2017.

Table 4-18 PV Investment and O&M cost

			PV house		PV public building	
	plant number		1	90,439	1	253
	capacity	kW	3.6	325,580	500	126,500
	Energy output	MWh/y	4.4	398,494	612	154,830
	Inv. Cost	EUR	9,055	818,959,929	1,153,846	291,923,077
	O&M	EUR/year	27	2,456,880	3,462	875,769
01-10year	Elec. Sale	EUR/year	881	79,698,826	98,858	25,010,948
11-20year	Elec. Sale	EUR/year	712	64,372,129	98,858	25,010,948

Table 4-19 Oil reduction by PV installation

			PV house		PV public building	
	plant number		1	90,439	1	253
	capacity	kW	3.6	325,580	500	126,500
	Energy output	MWh/y	4.4	398,494	612	154,830
	Oil Reduction	kL/year	1.0	90,458	139	35,146
	Oil Red. Cost(now)	EUR/year	465	42,097,840	64,650	16,356,564
	Oil Red. Cost(high)	EUR/year	829	74,941,113	115,088	29,117,388
Oil cost(now 2017); 60.5yen/L(0.465€/L)、					60.5	yen/Lcurrent(2017)
Oil cost (high 2008); 107.7(0.828)				130yen/€	107.7	yen/L max.(2008)

4.5.2 Solar Heating

4.5.2.1 Select solar heating system

In this analysis as RE technologies for heating a solar thermal heating system and ground source heat pump system are chosen. In this section a solar heating system for a residential house and a large solar heating and cooling system for a public building are investigated.

Table 4-20 Various Solar Heating Systems [40]

	Direct	Domestic Hot Water	Big Heating
			
Investment cost	300,000yen (2,308€)	900,000yen (6,923€)	250,000yen/m2 (1,923€/m2)
Spec	4m2, 200L	4m2, 200L	

Domestic hot water solar heating system for personal house and big heating system for public building

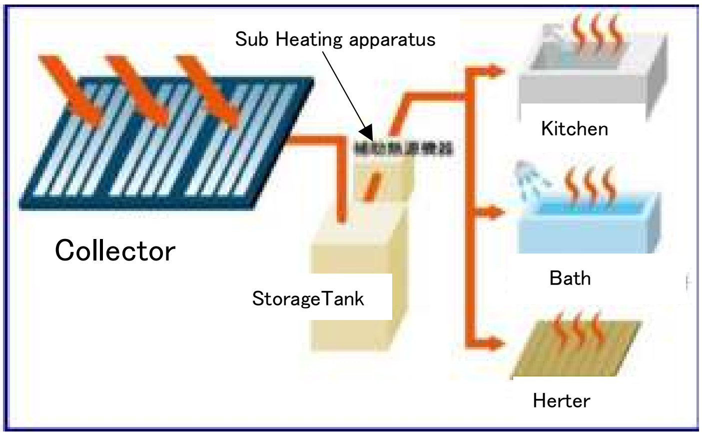


Fig.4-16 Domestic Hot Water Heating System [41]

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[40] Forum for promoting Solar Energy Utilization (2015): Introduction of merit of Solar Heating System and how to promote it, https://www.kankyo.metro.tokyo.jp/energy/renewable_energy/attachement/H27_kyutokenshiseminar_taiyounetsu.pdf - accessed 4 October 2017

[41] *ibid.*

4.5.2.2 Ecological point of Solar heating installations

GHG reduction
According to Fig. 3-2 GHG reduction of PV is calculated and the results are shown in Table 4-21.

Table 4-21 GHG reduction for Solar heating supply in Tottori west

			reduction
	Solar	Oil	GHG
GHG Emissions Intensity of	t-CO2 e/GWh	80	380	
Elec. Generation	t-CO2 /year	15,520	73,720	58,200

4.5.2.3 Economic point of Solar heating installations

Table 4-22 Solar Heating Investment Cost

			Solar house		Solar public building	
	plant number		1	90,439	1	253
	capacity	kW	1.5	135,659	9	2,277
	Energy output	MWh/y	1.8	166,039	110	27,869
	Inv. Cost	EUR	6,923	626,116,154	461,538	116,769,231
	O&M	EUR/year	21	1,878,348	1,385	350,308
	kerosin reduction	EUR/year	285	25,748,852	17,083	4,321,892

4.6 **Ground source heat pump(GSHP)**

4.6.1 Technology of GSHP

The temperature in the ground is more stable than the outside air temperature. In summer high energy in a house is released to the underground. In winter energy from the underground rises temperature in a house (Fig. 4-17, 4-18).

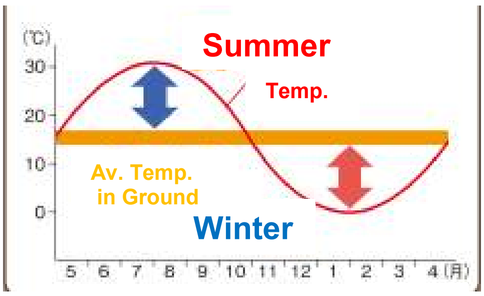

Fig. 4-17 Temperature t outside and underground [42]

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[42] SUNPOT Co. Ltd, (2016): Ground Source Heat Pump Catalogue, http://www.sunpot.co.jp/products/catalogue/ - accessed 6 October 2017

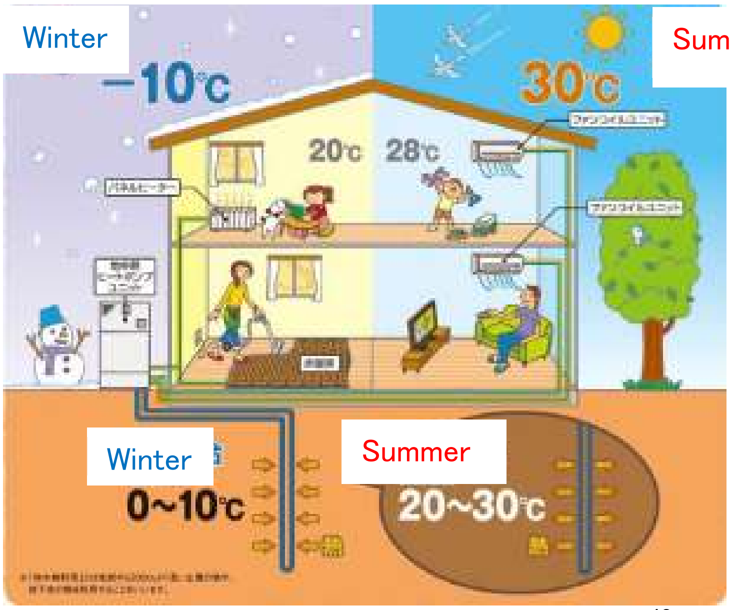

Fig.4-18 Ground Source Heat Pump System [43]

Investment cost of GSHP system for personal house is shown in table 4-23. RE systems for heating or cooling has no national subsidies function in Japan like FIT, but some local governments support to promote this system.
In this report I do not consider the subsidies for this system.

Table 4-23 GSHP investment cost [44]

	Mil. yen	euro
Pore hall	1.0	7700
Heat pump unit	0.8	6200
Radiant ceiling + Counstrution	0.9	6900

<130yen/euro>

[43] SUNPOT Co. Ltd, website (2017): http://gshp-sunpot.jp/feature.html - accessed 6 October 2017
[44] Nagano K. (2009): Ground Source Heating System for Home usage, http://www.pref.aomori.lg.jp/soshiki/energy/enerugi/files/handout_No.2-1.pdf - accessed - 7 October 2017

4.6.2 Economical points of GSHP installation

Table 4-24 GSHP Investment and O&M cost

		GSHP	
plant number		1	25,110
capacity	kW	10	251,100
Energy output	MWh/y	39	976,277
Inv. Cost	EUR	20,769	521,515,385
O&M	EUR/year	62	1,564,546
kerosin reduction	EUR/year	1,217	30,555,586

Table 4-25 Oil reduction by GSHP installation

		GSHP	
plant number		1	25,110
capacity	kW	10	251,100
Energy output	MWh/y	39	976,277
Oil Reduction	kL/year	9	221,615
Oil Red. Cost(now)	EUR/year	4,107	103,136,134
Oil Red. Cost(high)	EUR/year	7,312	183,599,366
Oil cost(now 2017); 60.5yen/L(0.465€/L)、			
Oil cost (high 2008); 107.7(0.828) , 130yen/€			

4.7 Small Hydro Power Plant installations for electricity In Tottori west

4.7.1 General information for SHPP

In Tottori Prefecture there are many mountains on the south side and Japan sea is on the north side. Three main river flow to Japan sea from southern mountains. The name is Hino, Tenjin and Sendai-river, from west to east.

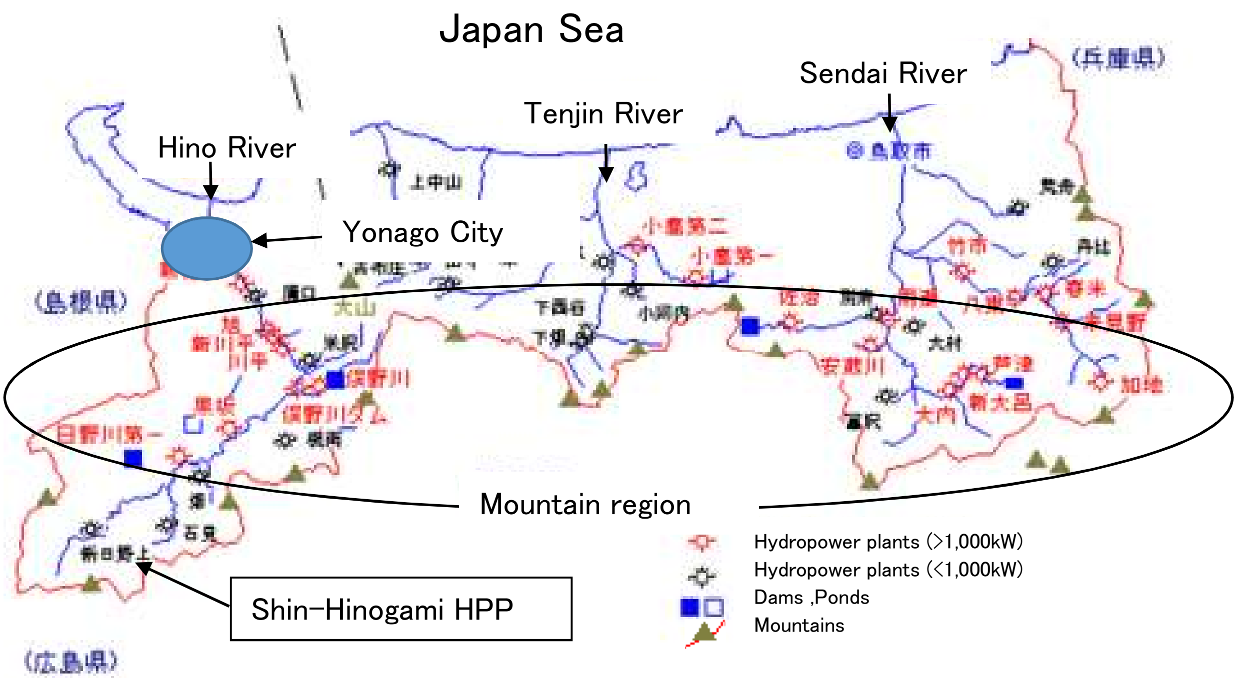

Fig.4-19 Hydro Power Plants map[45]

In this report I select better turbine for a hydropower plant. I select a real hydropower plant on the Hino river in Tottori. One is Shin-Hinogami power plant (Capacity is 660kWel).

[45] Hydro Power Plant Map in Tottori: http://www.geocities.jp/shuji_maru/tottori/map/01.htm - accessed 24 August 2016

4.7.2 Selection of SHPP

P(kW) = Q(m3/s) × H(m) × η_{ot} × 9.81(m/s2) η_{ot} ; total efficiancy

In the Table 14 η_{ot} is calculated from the values of P, Q H.

Table 4-26 Selected a Hydro Power Plant on the Hino River and model plant [46]

	P (Rated Capacity)	Q (Flow)	Head (Head drop)	η_{ot}
	kW	m3/s	m	
Shin-hinogami (real plant) 1)	660	4	23	0.731
Calculated basic plant	500	3.0	23	0.731

1) Location of Hino River is the west side in Tottori (Fig. 5-19)

We need 24MW capacity SHP plants in Tottori west (Table 4-6). As one SHP plant capacity is 500kW, the number of plants is 48.

4.7.3 Ecological point of SHPP installations

GHG reduction
According to Fig. 5 GHG reduction of HPP is calculated and the results are shown in Table 4-27.

Table 4-27 GHG reduction in SHP electricity supply

				reduction
		SHP	Oil	GHG
GHG Emissions Intensity of	t-CO2 e/GWh	26	735	
Elec. Generation	t-CO2 /year	2,808	79,380	76,572

[46] Tottori HPPs along to upstream of Hino river : http://www.geocities.jp/shuji_maru/tottori/hinogawa/index.htm - accessed 24 October 2016

4.7.4 Economical point of the SHPP installations

The cost for Investment and O&M are calculated by the value of Table 4-28.

Table 4-28 HPP sample of cost simulation [47]

Ref. No.	Scale	Inv. Cost	O&M Cost
1	100kW-300MW	$2,000-4,000/kW	5 - 10 cent/kWh
(IEA)		160-320k yen/kw	4 - 8 yen/kWh
	>300MW	$1,000-2,000/kW	1.8 - 10 cent/kWh
		80-160k yen/kW	1.4 - 8 yen/kWh
2	200kW	800k yen/kW	19.1 - 22.0 yen/kWh
(Japan)	12MW	850k yen/kW	10.6 yen/kWh

Table 4-29 Comparison with two 500kWel SHP plants investment costs

		500kWel new construction	500kWel using old equipment
Investment unit cost	k-yen/kW	800	500
	EUR/kW	6,154	3,846
Investment cost	EUR	3,076,923	1,923,077
Investment horizon	EUR	20	20
WACC	EUR	2.25	2.25
NPV	EUR	-1,153,173	673
Annuity	EUR	-72,237	42
LRGCel	EUR/MWh	255	223
Electricity generation	MWh/year	2,238	2,238
			130yen/€

Case study of using 800k yen/kW for investment cost is that NPV is negative. For this project proceeding Investment cost must be reduced.

I will discuss the case of using 500k-yen/kW investment cost.

[47] Ref. 1: 2011,IEA Deploying Renewables – Best and Future Policy Practice
Ref 2: 2011, Japan Energy Environment Meeting -Cost Inspection Commission NEDO (2014), "a White Paper on the Technology of Renewable Energy", http://www.nedo.go.jp/library/ne_hakusyo_index.html - accessed 16 March 2016

Table 4-30 SHP plant Investment and O&M cost

			SHP	
	plant number		1	48
	capacity	kW	500	24,000
	Energy output	MWh/y	2,238	107,424
	Inv. Cost	EUR	1,923,077	92,307,692
	O&M	EUR/year	378,738	18,179,446
01-10year	Elec. Sale	EUR/year	499,246	23,963,815
11-20year	Elec. Sale	EUR/year	499,246	23,963,815

Table 4-31 Oil reduction by SHP plant installation

			SHP	
	plant number		1	48
	capacity	kW	500	24,000
	Energy output	MWh/y	2,238	107,424
	Oil Reduction	kL/year	508	24,385
	Oil Red. Cost(now)	EUR/year	236,427	11,348,519
	Oil Red. Cost(high)	EUR/year	420,880	20,202,240
Oil cost(now 2017); 60.5yen/L(0.465€/L)、				
Oil cost (high 2008); 107.7(0.828)				130yen/€

4.8 **Organization**

4.8.1 Organization of RE stakeholders

How to organize the stake holder to proceed the RE transition. The knowledge from the succeed regions are blow 6 points.

1) Competence development -education and training investment
2) Investment in RE R&D facilities and activities
3) Marketing, branding and promotion of RE
4) Municipal/ regional government ownership of RE production facilities or energy utilities
5) Maximize opportunities for citizen participation and the development of new business models
6) Educate and inform citizens and businesses

No.1) - 4) [48]

No. 5), 6) [49]

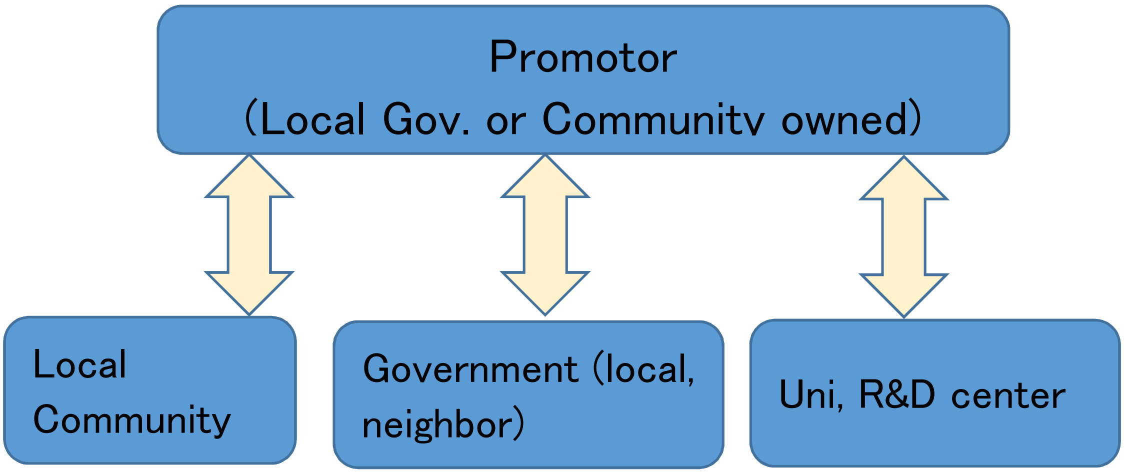

Fig. 4-20 RE promotion organization

[48] Bryden J., Linking RE to Rural Dev. "Issues from the OECD study and Report",(2012):Linking Renewable Energy to rural development (2012) OECD http://nilf.no/green_innovation_research/pdf_green_innovation_research/presentation_john_bryden-nilf.pdf - accessed 10 October 2017

[49] Toby D. Couture et al.: How to Achieve 100% Renewable Energy. (2014): http://www.medspring.eu/sites/default/files/How-to-achieve-100-percent-renewable-energy.pdf, accessed 16 May 2017

A promoter as a RE supplier must connect three important stakeholders which are local communities, local/neighbour government and universities and/or governmental/private R&D center.

4.8.2 Investment in RE R&D facilities and activities

Local generation and heating supplier should have R&D section, according to make situation of competition of technology supply companies each other, renew their equipment and enter the new RE field.

4.8.2.1 Combination of each RE plant for cost down

Usually RE plant or facility is more expensive than normal fossil fuel one. Especially RE facilities for solar heating and GSHP are not easy to promote quickly.
It is important to decrease the cost of RE facilities. One case is shown in Fig. 4-21. Combination of solar heating and GHSP is better solution of this problem.

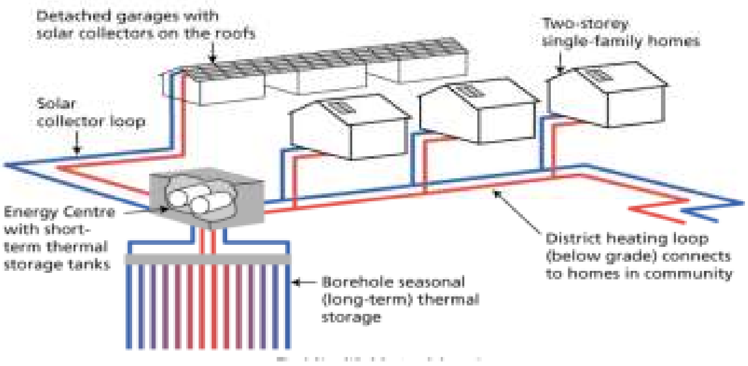

Figure 150: Solar Seasonal Storage and District Heating Loop

Fig.4-21: Solar Seasonal Storage and District Heating Loop In Canada [50]

[50] Weiss W. "Solar Energy – Solar Heating & Cooling" MSc Module 3

4.8.2.2 Expand PV installation area

Rice growing fields can be use with solar panels (Fig. 4-22).

Fig.4-22 Solar Sharing PV and Rice Growing [51]

There many rice fields in Japan. The new solar PV business is combining with rice fields. Rice can grow by full sunshine. In the field growing rice PV panel is partially installed. The possibility of PV installed area will be so huge.

4.8.3 Balancing

I do not discuss about energy balancing in this report.

Fig. 4-23 shows typical home energy consumption in Japan. It is clear that energy consumption increases in winter for heating. It is the difficult issue how to store summer energy for winter. A dam and a forest have a function of long term energy storage function.
Next step the technology of "power to gas" is very important. RE electricity can be stored long term by gas of hydrogen or methane.

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[51] Ishida M. (2016): Solar sharing PV and Rice Growing, http://www.itmedia.co.jp/smartjapan/articles/1602/01/news039.html accessed 14 September 2017

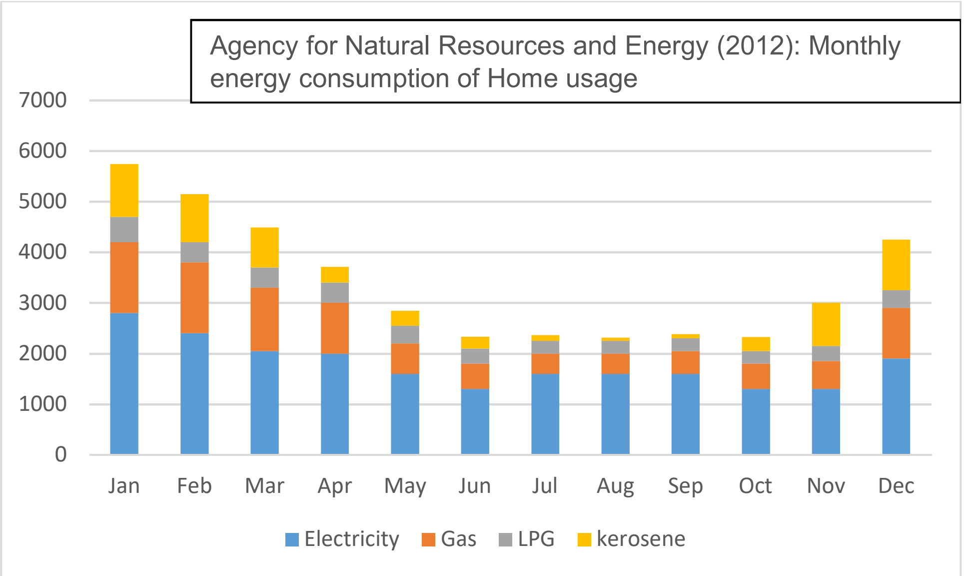


Fig. 4-23 Monthly energy consumption in Japan

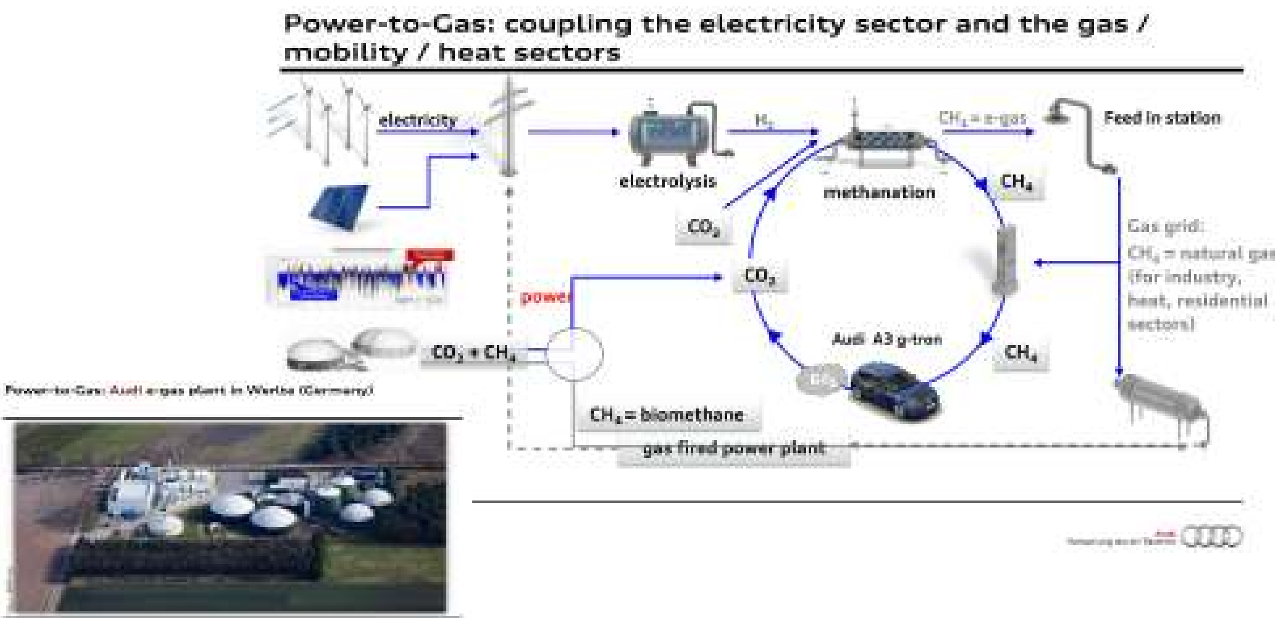


Fig. 4-24 "Power to gas: coupling the electricity sector and the gas / mobility /heat sector [52]

Lithium-ion battery has a short term energy storage function. Although the EV battery prices are the neck for market spreading, they have fallen recently. In transportation field, the price falling speed is so fast. Next, a battery for home use price will be fallen.

[52] Pengg H., "Decarbonization of the transport sector" MSc program Module 9

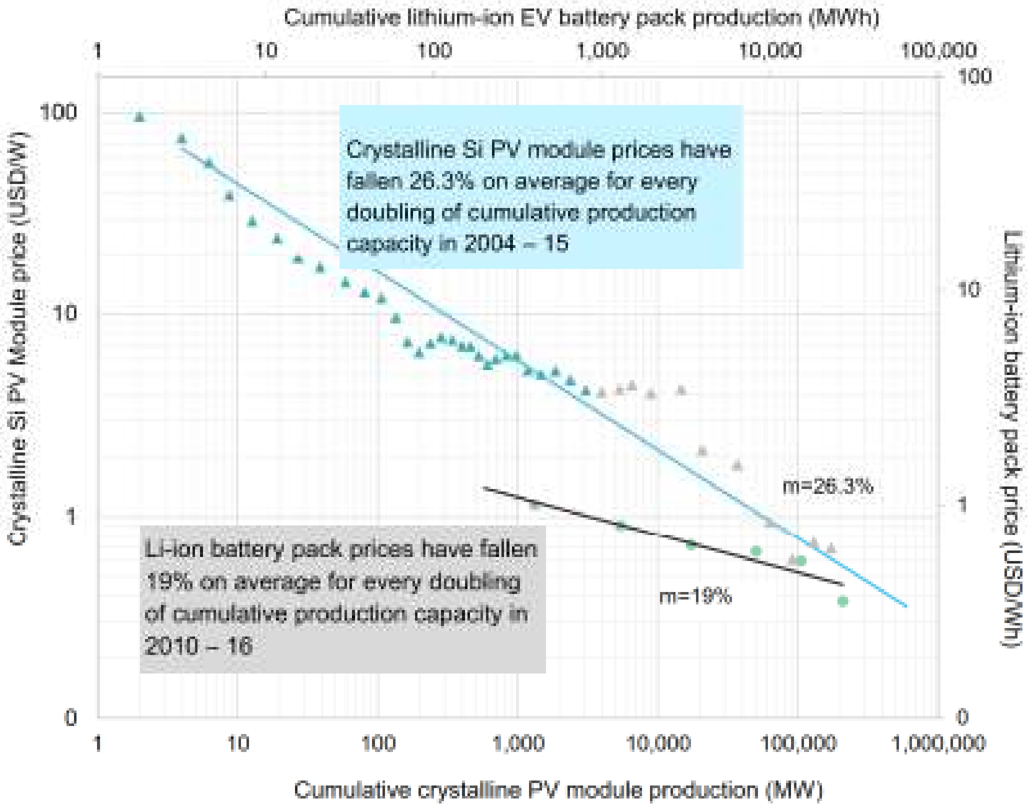


Fig. 4-25 Lithium-ion Battery experience curve [53]

[53] Zamorano A. (2017): Global EV trends and forecast, thttp://docketpublic.energy.ca.gov/PublicDocuments/17-IEPR-07/TN217132_20170417T164544_Global_EV_trends_and_forecast.pdf - accessed 10 October 2017

5 Summary

5.1 Target setting

Table 5-1 Energy situation and 100% RE target in Tottori

GWh/year	Electricity			Heating			Total			Tottori
	East	Middle	West	East	Middle	West	East	Middle	West	Total
Demand(2014)	1,579	708	1,605	2,332	1,046	2,371	3,911	1,754	3,976	9,640
Potential	1,548	694	1,307	2,951	1,505	2,944	4,499	2,199	4,250	10,948
Current RE(2015)	589	264	598	65	29	66	653	293	664	1,610
Target 2050	789	354	803	1,166	523	1,186	1,955	877	1,988	4,820

100%RE Target is determined by a half demand in 2014 (Table 5–1). It is possible to reach the target by improving energy efficiency and energy saving.

Table 5-2 RE plant types in Tottori west

	Electricity							Heating			
	PV house	PV public	PV Sum	Wind	SHP	Biomss	Total	Solar	Ground	Biomass	Total
MW	341	132	474	100	24	3.0	598			10	
GWh/y	377	146	523	152	108	19	803	366	794	25	1,186

According to the energy potential each region, SHP and Biomass plants will be installed firstly and next PV one.
In Tottori west region, the ability of each RE facilities is decided in Table 5-2.

5.2 Ecological assessment

5.2.1 GHG Reduction

GHG emissions were calculated by the number in Fig.3–2.

Table 5-3 GHG reduction by energy efficiency and renewable electricity plant

		Electricity						reduction
		PV	Wind	SHP	Biomss	Total	Oil	GHG
GHG Emissions Intensity of	t-CO2 e/GWh	85	26	26	45		735	
Elec. Generation	t-CO2 /year	44,477	3,960	2,808	854	52,099	589,874	537,775
	reduction	Energy		reduction				Efficiency
	GHG	Efficiency	Oil	GHG				+ Elec.
GHG Emissions Intensity of	t-CO2 e/GWh	0	735					
Elec. Generation	t-CO2 /year	0	589,874	589,874				1,127,649

GHG reduction by energy efficiency and RE electricity plants installation is 1,127,649 t-CO2/year (Table 5–3).

GHG emissions were calculated by the number in Fig.3-3.

Table 5-4 GHG reduction by energy efficiency and renewable energy heating plant

		Heating/Cooling					reduction
		Solar	Ground(*)	Biomass	Total	Oil	GHG
GHG Emissions Intensity of Heating Generation	t-CO_2 e/GWh	80	0.2	50		380	
	t-CO_2 /year	15,520	195	650	16,365	449,538	433,173
	reduction GHG	Energy Efficiency	Oil	reduction GHG			Efficiency + heat
GHG Emissions Intensity of Heating Generation	t-CO_2 e/GWh	0	380				
	t-CO_2 /year	0	449,538	449,538			882,711

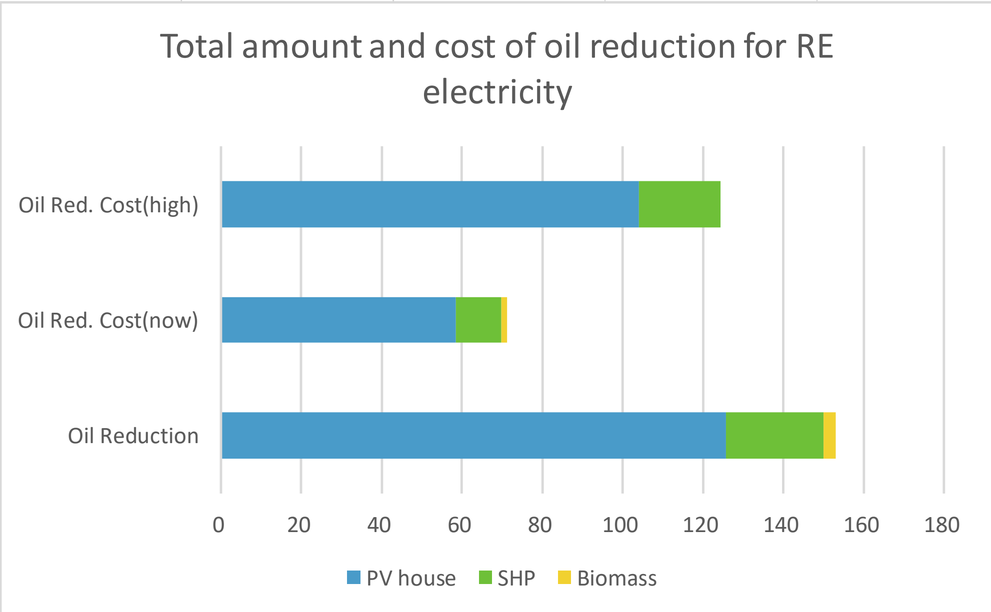
(*) Ground Heating system has no data. Assume GHG emissions intensity of Ground Heating equals Geothermal one

GHG reduction by energy efficiency and RE heating plants installation is 882,711 t-CO_2/year (Table 5-4).

The energy demand target in 2050 was fixed a half number in 2014 by energy saving and improving energy efficiency. That means the GHG decreased same value of total GHG emission of electricity and heating by oil.
And more GHG emission of switching from oil to RE will be decreased 538k t-CO_2/year (Elec.) and 356k t-CO_2/year (Heating). Total GHG emission is 95%.

Table 5-5 Total amount and costs of Oil reduction by RE electricity generation

		PV house	SHP	Biomass
plant number		90,692	48	3
capacity	kW	452,080.4	24,000	3,000
Energy output	MWh/y	553,323.8	107,424	12,690.2
Oil Reduction	ML/year	125.6	24.4	2.9
Oil Red. Cost(now)	Mil.-EUR /year	58.5	11.3	1.3
Oil Red. Cost(high)	Mil.-EUR /year	104.1	20.2	

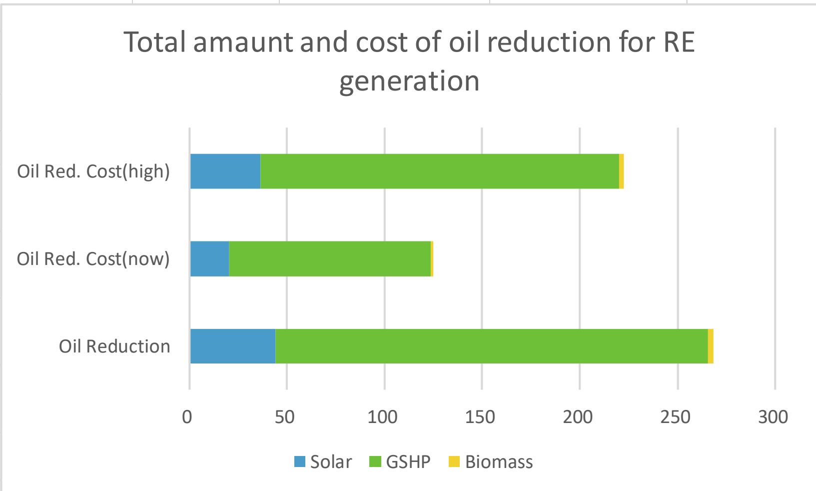


5.2.2 Oil reduction

Total amount of oil reduction from oil to RE is 153 Mega litter per year and cost is from 70 to 130 Million euro per year.

Table 5-6 Total amount and costs of Oil reduction by RE heat/cooling

		Solar	GSHP	Biomass
plant number		90,439	25,110	3
capacity	kW	137,936	251,100	3,000
Energy output	MWh/y	193,909	976,277	12,690
Oil Reduction	10^6 L/year	44.0	221.6	2.9
Oil Red. Cost(now)	Mil. EUR/year	20.5	103.1	1.3
Oil Red. Cost(high)	Mil. EUR/year	36.5	183.6	2.4



5.3 **Economical assessment**

5.3.1 Electricity

Total RE plants investment cost is 1,233 million euro and the electricity sales income is ca. 120 euro per year. It means the payback period is about ten years. In the economic point of view these investment is good financial projects.

Table 5-7 RE plants investment and O&M costs and income

			Total
	Energy output	MWh/y	673,438
	Inv. Cost	Million EUR	1,233
	O&M	Million EUR/year	22
01-10year	Elec. Sale	Million EUR/year	133
11-20year	Elec. Sale	Million EUR/year	118

5.3.2 Heating and Cooling

Table 5-8 RE plants for Heating and cooling investment and O&M costs

					130yen/EUR
		biomass(CHP)	Solar Heating		GSHP
		1000kW	1.5kW	90kW	10kW
Inv. Unit cost	yen/kW				
	EUR/kW				
Investm. Cost	EUR	10,000,000	6,923	461,538	20,769
Investm. Horizon	year	20	20	20	20
O&M cost	EUR	138,004	21	1,385	62
production El.	MW/yr	6.0	—	—	—
Energy output (hot/cool water)	MW/yr	21.3	1.8	110.2	38.9
FLH	hr/yr	7,848	1,224	1,224	1,488
Fuel Cost	EUR/yr	1,408,205	0	0	0
Feedstock		yes	no	no	no
NPV	EUR	3,154,741	-2,710	-210,941	-9,773
LRG	EUR/MWh	365	248	275	35
C.U.F	%	90%	14%	14%	17%

In the economical point of view, it is difficult for investment of the RE facilities for heating or cooling. Some local governments support these projects, but they are not as popular as FIT system.

A residential house usually has own heating/cooling system. In some northern regions in Japan central heating system is proceeded like Shimokawa (Fig. 2-3) by biomass CHP plant. GSHP system is not popular and expensive now. RE plant for heating should be promoted by subsidizing and technical innovation.

6 Conclusions

As documented in the introduction the objective of this work is to answer the following questions for a specific region:

- How to fix the 100%RE target in the region?
- How much money are flowing out for fossil fuel?
- How much GHG are emitted?
- How much money will be needed for investment and O&M of RE plants?
- How to organize people to proceed the transition to RE systems?

6.1 Target setting in 2050

First, check the current energy demand and RE potential in the examining region. Nest step, 50% decrease of current demand by improving energy efficiency and energy saving. RE of Biomass, SHP plants and some ratio Solar energy will be installed for energy supply. Wind energy plant is suitable for installation mainly northern region in Japan. They are Hokkaido and northern area in Tohoku.

6.2 Stop to flow money for fossil fuel and GHG emission

According to high energy efficiency and transition from oil to RE, much oil consumption and GHG emission will be decreased.

6.3 Investment and O&M costs for RE plants

Costs for RE plants investment and O&M are very expensive. In this report I only used FIT for investment, but there are many national and local subsidies. In the future the subsidies will be decrease, but the cost of RE equipment will be decrease, especially new technology.

It is difficult to construct for RE plant for heating or cooling supply, as there is no good system like FIT for RE electricity. But some local governments and banks are supporting to loan of RE plants and organize a fund of local citizen.

6.4 Organization

It is important that a project promotor communicate to many stakeholders. Many RE projects could not succeed by no information to local community. Education for RE is important as same as information. Promotors should work with persons in local University or R&D centre for getting new technology and education to local community. Of course, promotors should contact to local government key persons in order to permit and license many things.

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List of abbreviations

FIT	Feed-in Tariff
PV	Photovoltaic
RE	Renewable Energy
GSHP	Ground Source Heat Pump
NEDO	New Energy and technology Development Organization in Japan
NPV	Net Present Value
GHG	Green House Gases
EUR	Euro
C.U.F.	Capacity Utilization Factor
HPP	Hydro Power Plant
SHPP	Small Hydro Power Plant
IEA	International Energy Agency
R&D	Research and Development
FLH	Full Load Hours
O&M	Operation and Maintenance
ZEH	Zero Energy House
METI	Ministry of Economy, Trade and Industry
CHP	Combined Heat and Power
ORC	Organic Rankine Cycle

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