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Renewable energies production based on territorial climate-energy plans

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EN GENIE DE L'AMENAGEMENT

La formation au génie de l'aménagement, assurée par le département aménagement de l'Ecole Polytechnique de l'Université de Tours, associe dans le champ de l'urbanisme et de l'aménagement, l'acquisition de connaissances fondamentales, l'acquisition de techniques et de savoir faire, la formation à la pratique professionnelle et la formation par la recherche. Cette dernière ne vise pas à former les seuls futurs élèves désireux de prolonger leur formation par les études doctorales, mais tout en ouvrant à cette voie, elle vise tout d'abord à favoriser la capacité des futurs ingénieurs à :

- Accroître leurs compétences en matière de pratique professionnelle par la mobilisation de connaissances et de techniques, dont les fondements et contenus ont été explorés le plus finement possible afin d'en assurer une bonne maîtrise intellectuelle et pratique,
- Accroître la capacité des ingénieurs en génie de l'aménagement à innover tant en matière de méthodes que d'outils, mobilisables pour affronter et résoudre les problèmes complexes posés par l'organisation et la gestion des espaces.

La formation par la recherche inclut un exercice individuel de recherche, le projet de fin d'études (P.F.E.), situé en dernière année de formation des élèves ingénieurs. Cet exercice correspond à un stage d'une durée minimum de trois mois, en laboratoire de recherche, principalement au sein de l'équipe Ingénierie du Projet d'Aménagement, Paysage et Environnement de l'UMR 6173 CITERES à laquelle appartiennent les enseignants-chercheurs du département aménagement.

Le travail de recherche, dont l'objectif de base est d'acquérir une compétence méthodologique en matière de recherche, doit répondre à l'un des deux grands objectifs :

- Développer toute ou partie d'une méthode ou d'un outil nouveau permettant le traitement innovant d'un problème d'aménagement
- Approfondir les connaissances de base pour mieux affronter une question complexe en matière d'aménagement.

Afin de valoriser ce travail de recherche nous avons décidé de mettre en ligne les mémoires à partir de la mention bien.

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SUMMARY

1. Renewable energies development's issues

Since the Rio earth summit in 1992, developed countries became more aware of how greenhouse gas (GHG) emissions contribute to global warming. It turns out that energy has an important impact on greenhouse emissions. As a matter of fact, 80% of European greenhouse emissions are due to the use and production of energy (A.Marreto, 2010). Besides, the demand of energy is growing up and fossil energies reserves are decreasing which leads to increase fossil energies costs (Chefurka.P, 2007).

To face climate change effects and volatile energy prices, European Union and France have fixed objectives. In 2010, the renewable energies production represented 12,4% of final consumption and some countries as Sweden are in advance with 48% renewable energies share of final consumption. In France, the renewable energies production represented 12% of final energy consumption in 2010. However, thanks to its nuclear and hydropower production its greenhouse gas emissions due to electricity production are lower than some countries as England for example.

In France, these objectives have to be handled by the cities as well in a document called territorial climate-energy plan. The aim of this research project is to quantify renewable energies production by looking at climate-energy plan's projects and to infer what infrastructures will be needed to achieve the objectives. First of all, we will check how these objectives are translated into ScOT's targets by 2020 and 2050. Then we will expose the method used to quantify the renewable energies production. Finally we will present the results of this study including its analysis.

2. Climate-energy plans 'objectives: too much ambitious?

The climate-energy plan is a guidance paper which gathers the required guidelines to follow in order to reach specific objectives by 2020 and 2050 at a local scale. In France, this document is a mandatory document that local authorities with at least 50 000 inhabitants have to draw up since the national climate-energy plan in 2004. Most of the local climate-energy plans have been written in 2007-2008. This territorial plan reaches two main objectives declared by European Union and France. The French objective called factor 4 is a national matter. It leads to cut greenhouse gases emissions fourfold below 1990 levels by 2050. The European objective called 3*20% is divided in three types of goals:

- Decreasing greenhouse gases emissions to 20% by 2020.

The greenhouse gases are responsible for the greenhouse effect as carbon dioxide, methane, ozone and fluocarbons.

- Rising energy efficiency up to 20% by 2020. We will not focus on this objective on this paper.
- Increasing renewable energy's share of gross of final energy consumption to 20% by 2020.

According to scientific literature, we can find different renewable energies definitions. But in general, a renewable is characterized by the fact that contrary to fossil energies "they can convert natural motion and variation into energy" (Leijon. M, 2010) and they are "environment-friendly and capable of replacing conventional sources in a variety of applications at competitive prices" (S. Cristobal.J.S, 2011). According to the European Commission, the gross or final energy consumption (GFC) means "the energy commodities delivered for energy purposes to end-users, including the consumption of electricity and heat by the energy branch for electricity and heat production and including losses of electricity and heat in distribution and transmission". In other words the GFC combines consumed energy from transportation, electricity and heat.

At this stage, no research has been made about territorial climate-energy plans or its ability to reach the European and French objectives by 2020 and 2050. Only some studies had focused on European targets and the appropriate policy to achieve its goals. In Europe, the debate about the relevance of these objectives is divided. For some people, the 3*20% are considered as ambitious meanwhile the European commission is confident by proclaiming Europe will overachieve its 20% reduction by 2020[1]. If these objectives can be reached at the European scale, why it could not be the same at a local scale? This is why in this paper, for all these reasons, we will take the opposite side by assuming that **the stated objectives of the climate-energy plan may not be achieved.**

[1] European Comission (2014). *Eu over-achieved first kyoto emissions target, on track to meet 2020 objective*. Available on : http://ec.europa.eu/clima/news/articles/news_2013100901_en.htm

3. Evaluation of the energy plans' projects feasibility towards its objectives

a. Case study of the ScOT of Tours: Current renewable energies production on the territory and its targets

This study focuses on the single case of the city of Tours at a ScOT scale which gathers the biggest city of Tours and 39 other cities around. The ScOT covers 830 km^2 and has a population about 363 000 inhabitants. Its climate-energy plan assures the objectives are being taken seriously and concrete initiatives have been engaged to reach it.

At the ScOT scale, the 20% GHG emissions reduction by 2020 and the factor 4 lead to 2 200 000 teq CO_2 emissions by 2020 and 687 500 teq CO_2 by 2050 as it is shown in this table:

YEAR	GREENHOUSE GAS EMISSIONS
1990 (reference year)	2 750 000 teq CO2
2006	2 900 000 teq CO2
Objective 2020	2 200 000 teq CO2
Objective 2050	687 500 teq CO2

TABLE 1: GHG EMISSIONS EVOLUTION ON THE SCOT TERRITORY

During this study, we will consider that GHG emissions goals will be reached by renewable energies production only.

Concerning renewable energies production, the aim is to increase renewable energy's share of final energy consumption to 20% by 2020. In order to know what would be the required renewable energies production to achieve the objective, it is important to calculate what would be the final energy consumption in the ScOT territory by 2020. In Europe, energy consumption increased by 10% from 1990 to 2000 (European Comission, 2002) and the growth in world energy consumption is about 2% per annum (Shafiee, 2009). Nevertheless, because of the loss of oil and gas over the years combined to a decreasing purchasing power in France, we are assuming in that case that final energy consumption per inhabitant will remain the same in 2020. This scenario is optimal by considering that the final consumption will not increase.

It is written in the ScOT diagnostic its population will grow up to 392 129 inhabitants by 2030. Which means an increase of 0, 48% per year in the number of inhabitants from 2009 to 2030. In 2009, the final energy consumption was about 0, 03 GWh. With the same consumption per habitant in 2020, the required renewable energies production to reach the 20% renewable energy's share of final energy consumption by 2020 is 2 213 GWh.

Year	Consumption of energy in Scot of Tours (GWh)	Number of inhabitants	Renewable energies production (GWh)	Renewable energy's share of final energy consumption
2009	10 500	354 815	223	2%
2020	11 065	373 894	2213	20%

TABLE 2: RENEWABLE ENERGIES PRODUCTION

In 2009, the current renewable energies production was about 223 GWh which represents 2% of final energy consumption. The following table details this production for each type or renewable resource.

BIOMASS		SOLAR THERMAL	
Annual production (Gwh)	169	Annual production (Gwh)	4,6
SOLAR PV		WIND POWER	
Annual production (Gwh)	14,3	Annual production (Gwh)	0,009
GEOTHERMAL		HYDROPOWER	
Annual production (Gwh)	1	Annual production (Gwh)	1
BIOGAS		**TOTAL**	
Annual production (Gwh)	33	**Annual production (Gwh)**	**222,9**

TABLE 3: TOTAL RENEWABLE ENERGIES PRODUCTION ON THE SCOT TERRITORY IN 2009

As we can see in this table, seven different types of renewable energies exit on the ScOT's territory. The energy production differs according to each type of energy resources. The biomass and biogas resources are consumed in a cogeneration centre to produce heat and electricity. The biomass refers to all organic matter of animal or vegetable origin. Usually and on the ScOT's territory, the main resources are the wood chips or wood pellets. As we can see on the table 3, the ScOT has focused its renewable energies production on the biomass resource. As the forest is an important resource on ScOT's territory (it represents one quarter of the territory), the ScOT has focused on exploiting it. The biogas is generated through the rotting of biomass. The main used resources are agricultural waste and food waste. The biogas potential is high as well because the region is the most important cereal region in France. The solar thermal captures solar energy to generate heat as well and is usually used to heat domestic water or housings. The solar PV captures also solar energy but to generate electricity. The wind turbines and hydroelectric dams convert natural movements (wind and water flow) into electricity. In the ScOT, the main exploited renewable resources are biomass, biogas and solar power. At this opposite, hydropower will not be developed on this territory. First, because the stream flows of La Loire are relatively low and secondly because it is registered on the UNESCO world heritage. Concerning geothermal resources, the ScOT has not focused on this energy and did not develop projects about it. That's why we will not take account of this resource in this study either.

b. Methodology: a demonstration divided into three sections

In order to validate the assumption, three stages are necessary by:

1. Quantifying renewable energies production based on the climate-energy plan's projects and ScOT factor 4.
2. Making scenarios by 2020 and 2050 of which infrastructures are necessary to meet the objectives.
3. Analyzing and comparing renewable energies production based on the climate-energy plan's infrastructures and those from the scenarios.

i. Renewable energies quantification

For the step n°1, the required literatures are the climate-energy plan and the ScOT factor 4 to determine what the projects are. The ScOT factor 4 is a strategic document which focuses more on necessary projects to achieve the same objectives. Based on the projects, it is necessary to model the problem. In other words, how to calculate renewable energies production? To answer that question, it is needed to identify the variables. To this end, the literature is based on scientific articles. The documents provide information concerning exogenous and endogenous variables which are necessary to calculate the production. The exogenous variable is an independent variable from external conditions that affects the system without being affected by it while an endogenous variable depends on other variables of the system. The scientific literature concerning renewable energies production or simulation focuses on solar PV power and Wind turbine power.

Solar PV power: R* S* I

Variable		Definition	Unit
R	Endogenous variable	Efficiency of the solar panels	It doesn't have an unit
S	Endogenous variable	Surface of the solar panels	m^2
I	Exogenous variable	Global irradiation	W/m^2

In this case the irradiation data is uploaded from helioclim data 2005. It gives irradiation values which have been measured for each hour of the year 2005 so 8760 data. There is also another solar PV simulation based on the article of Edward Rajan, S which is more complex and integrates cloudness parameter. This simulation will only be used as an optimal (Table in appendices). For both simulations, we made the hypothesis that all the solar panels are angled at a tilt angle of 30 degrees and an azimuth of 0 (due south). What's more, the solar PV power has been calculated with 2 different efficiencies: one with an efficiency of 0, 15 (the worst we can find on the market) and 0, 19 (the best we can find). As well, we do not take into account the shading mask. This context is optimal. In this way, we can know if the climate-energy plan is about to achieve the objectives with the best conditions.

Wind turbine power : $n * \frac{1}{2} * A * \rho * v^3$

Variable		Definition	Unit
A	Endogenous variable	Swept area by the turbine's pales	m^2
ρ	Exogenous variable	Air density	Kg/m^3
v	Exogenous variable	Wind speed	m/s
n	Endogenous variable	Number of wind turbine	It doesn't have an unit

Source: Kaldellis, J.K. (2003) *Parametric investigation concerning dimensions of a stand-alone wind power system.* Applied Energy 77; p35-50

In this case we consider that the air density is stable and equals to 1,225 kg/m^3. For calculations, the swept area by the turbine's pales corresponds to a turbine which has a 92 m diameter. The details of these calculations are in the appendices. The wind data have been retrieved from Tours-Saint Symphorien's weather station. These data have been measured for each hour of the year 2013 so 8760 wind data.

Second of all, these variables have been implemented in the software Matlab under toastersystem. The data have been afterwards entered into toastersystem in order to calculate renewable energies production.

ii. Required infrastructures quantification from the scenarios

For the step n°2, the method is quite the same but in a different manner. Indeed, in order to know what infrastructures will be needed to reach the objectives, we already know what the required renewable energy production is. We take the same model and the variables implemented into toastersystem but we change the value of endogenous variables to reach the required renewable energies production.

For the step n°3, we will compare the infrastructures that the climate-energy plan and the ScOT factor 4 propose and those from the scenarios. Thanks to this analysis, we can determine if the climate-energy plan's objectives are feasible.

iii. Avoided GHG emissions evaluation

The renewable energies production does not emit greenhouse gases (wind power, solar PV and thermal solar power) or much less than non-renewable energies production (biomass and biogas power). When we talk about GHG emissions reduction, we actually use talk about "avoided GHG emissions". In other words, the avoided GHG emissions are associated with a renewable energy production when this one replaces a non-renewable energy production which emits these GHG. The thing is: which renewable energy has to replace a specific non-renewable energy? We have to determine first, what are the consumed non-renewable energies in the final energy consumption. But also, the use of each energy has to be the same. In 2008, the different types of sources in the final energy consumption of the central region (about 74, 6 TWh) were spread in this configuration:

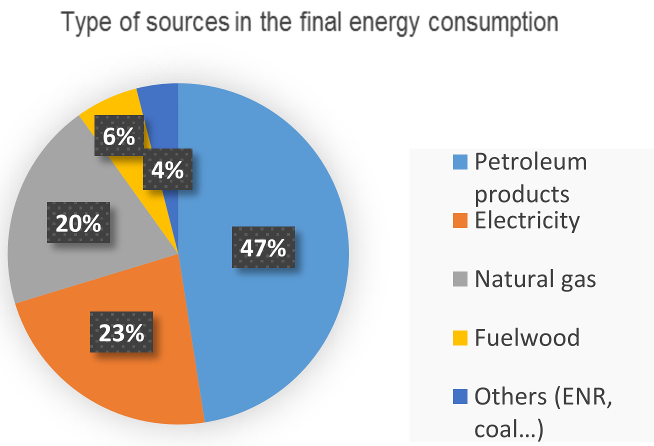

FIGURE 1: TYPE OF SOURCES IN THE FINAL ENERGY CONSUMPTION OF THE CENTRAL REGION (2008)
Source : SRCAE (Schéma Régional du Climat, de l'air et de l'énergie) région Centre

If this distribution is the same for the ScOT, the most consumed energy resources are petroleum products, electricity and natural gas. Even if electricity is manly produced by nuclear power in France and does not emit GHG, it is also produced by natural gas or fuel during peak demands (especially during winter months). This is why, we consider that electricity emit GHG when it is used for heat.

Type of source	GHG emissions per KWh of final energy (Gco2/KWh)
Natural gas	202
Coal	360
Fuelwood	7
Fuel	276
electricity	180

FIGURE 2: GHG EMISSIONS PER KWH OF FINAL ENERGY FOR HEAT

If we do not consider natural gas as a resource to produce electricity, 34% of this source of energy is mainly used to produce heat for a residential use (electricity: 29%, fuel: 18%). This is why, we will consider the avoided GHG emissions associated with energy production from biomass, biogas and solar thermal from natural gas GHG emissions. The wind turbines and solar PV produce electricity as nuclear power. The fuel is a petroleum product but it is also the third biggest source of energy consumed to produce heat for residential use. As well, the petroleum products are the first type of energy consumed in the gross energy consumption. We will consider in this case that avoided GHG emissions associated with energy production from solar PV and wind turbines are equal to natural gas GHG emissions.

BIOMASS		WIND TURBINES	
Avoided GHG emissions per KWh of final energy (Gco2/KWh)	202	Avoided GHG emissions per KWh of final energy (Gco2/KWh)	276
BIOGAS		**THERMAL SOLAR**	
Avoided GHG emissions per KWh of final energy (Gco2/KWh)	202	Avoided GHG emissions per KWh of final energy (Gco2/KWh)	202
SOLAR PV			
Avoided GHG emissions per KWh of final energy (Gco2/KWh)	276		

TABLE 4: AVOIDED GHG EMISSIONS FOR EACH TYPE OF RENEWABLE ENERGY

4. Results and confrontation between ScOT' projects and scenarios

a. ScOT's renewable energies production and GHG emissions by 2020

i. ScOT 's renewable energies production by 2020

First of all, the climate-energy plan is not that concrete as it is said. Indeed, this document set out all the projects excepted wind power development, thermal solar and private solar PV development. The wind power development is a separate case. Indeed, this development is done by the region which identifies specific areas where the wind potential is high called ZDE (Zone de Développement Eolien or wind power development zone). The south of the ScOT is concerned by one of them. The projects that the ScOT has thought about to achieve renewable energies by 2020 are presented below:

BIOMASS		*Solar farm in Larcay*	
Biomass central (Saint pierre des corps)		Solar panels surface (m²)	200 000
Housing	14 000	Citizens and business	
Wood quantity (tonnes)	92 000	Solar panels surface (m²)	2 400 000
BIOGAS		*Landfill*	
Landfill (sonzay)		Solar panels surface (m²)	50 000
Purification plant		**WIND TURBINES**	
SOLAR PV		*12 wind turbines*	
Tramway maintenance center		**THERMAL SOLAR**	
Solar panels surface (m²)	1 500	Solar panels surface (m²)	180 000
Boulodrome			
Solar panels surface (m²)	1 200		

TABLE 5: TOTAL PROJECTS BY 2020

The more developed by the ScOT are the solar PV, wind power and biomass. It is necessary to take into account the renewable energies development by the private (citizens and business activity) especially for solar PV development and thermal solar development.

The table 6 is the result of the different types of renewable energies production. The database helioclim is the one which has been used to calculate solar PV production. The annual production represents the power generated by the project for a year. The total energy production combines the project's energy production and the one from 2009 for each type of renewable energy.

BIOMASS		*Solar farm in Larcay*	
Biomass central (Saint pierre des corps)		Annual production (GWh)	Min : 41,76 Max : 52,89
Annual production (GWh)	133	Citizens and business	
Total energy production (GWh)	**302**	Annual production (GWh)	Min : 501 Max : 634
BIOGAS		*Landfill*	
Landfill (sonzay)		Annual production (GWh)	Min : 10,44 Max : 13,22
Annual production (GWh)	20	**Total energy production (GWh)**	**Min : 553,75** **Max : 700,8**
Purification plant		**WIND TURBINES**	
Annual production (GWh)	5,29	*12 wind turbines*	
Total energy production (GWh)	**58,3**	Annual production (GWh)	31
SOLAR PV		**Total energy production (GWh)**	**31**
Tramway maintenance center		**THERMAL SOLAR**	
Annual production (GWh)	Min : 0,31 Max : 0,40	Annual production (GWh)	189,1
Boulodrome		**Total energy production (GWh)**	**193,7**
Annual production (GWh)	Min : 0,25 Max : 0,32		
TOTAL			
Total energy production (GWh)		**Min : 1 140, 7** **Max : 1 287,8**	
Renewable energy's share of final energy consumption		**Min: 10,3%** **Max: 11,6%**	

TABLE 6: TOTAL RENEWABLE ENERGIES PRODUCTION BY 2020 BASED ON THE CLIMATE-ENERGY PLAN AND SCOT FACTOR 4

The min represents the renewable energies production with a solar PV production with an efficiency of 0, 15. We can see with all the known projects, the final energy production is at least 1 105, 7 GWh or the best is 1252, 8 GWh which means a 10% or 11% renewable energy's share of final energy consumption. The objective 3*20% is to achieve 2 213 GWh by 2020. Even if we use the other solar PV power simulation with an annual global irradiation of 2 300 KWh/m² (equivalent to a solar gain in Australia), the total energy production will be at least 1 514, 3 GWh (with an efficiency of 0, 15) or 1 759, 2 GWh (with an efficiency of 0, 19). Which means a 13, 7% or 15, 9% renewable energy's share of final energy consumption. So even with an optimal global irradiation, the 20% is not reached.

It seems that the ScOT of Tours may not achieve the 20 % renewable energy's share of final energy consumption. Since this project has been made, it is most likely that the ScOT will update others projects to achieve these objectives that we are not aware of. Even though, the objective 20% renewable energy's share of final energy consumption by 2020 seems complicated to reach. Between 2009 and 2013, the ScOT achieved 3 projects (solar PV panels on the Tram maintenance center, the biomass plant and both biogas projects) excluding private renewable energies development. In 4 years, the territory has developed 158, 6 GWh renewable energies production.

ii. ScOT's GHG emissions by 2020 based on renewable energies production

With these results, the avoided GHG emissions have been calculated for each project and for each type of renewable energy.

BIOMASS		*Solar farm in Larcay*	
Biomass centrale (Saint pierre des corps)		Annual production (GWh)	Min : 11 537 Max : 14 600
Avoided GHG emissions (teq CO2)	26 866	Citizens and business	
Total Avoided GHG emissions (teq CO2)	**60 606**	Annual production (GWh)	Min : 138 276 Max : 174 984
BIOGAS		*Landfill*	
Landfill (sonzay)		Annual production (GWh)	Min : 2 870 Max : 3 643
Avoided GHG emissions (teq CO2)	4 040	**Total Avoided GHG emissions (teq CO2))**	**Min : 155 404** **Max : 195 991**
Purification plant		**WIND TURBINES**	
Avoided GHG emissions (teq CO2)	1 069	*12 wind turbines*	
Total Avoided GHG emissions (teq CO2)	**11 699**	Avoided GHG emissions (teq CO2)	**8 556**
SOLAR PV		**Total Avoided GHG emissions (teq CO2)**	**8 556**
Tramway maintenance center		**THERMAL SOLAR**	
Avoided GHG emissions (teq CO2)	Min : 86 Max : 110	Avoided GHG emissions (teq CO2)	52 164
Boulodrome		**Total Avoided GHG emissions (teq CO2)**	**53 244**
Annual production (GWh)	Min : 69 Max : 88		

TOTAL	
Total Avoided GHG emissions (teq CO2)	**Min : 289 929** **Max : 330 516**
Total emitted GHG emissions (teg CO2) by 2020	**Min: 2 460 071** **Max: 2 419 484**

TABLE 7: AVOIDED GHG EMISSIONS BY 2020 BASED ON RENEWABLE ENERGIES PRODUCTION

With these projects, the ScOT of Tours will emit between 2 460 071teq CO2 and 2 419 484 teq CO2 by 2020. The goal is to obtain 2 200 000 teq CO2 emissions by 2020. In this case, the ScOT will not achieve 20% GHG emissions reduction by 2020 thanks to its renewable energies production.

b. Scenarios for 2020 and 2050: the necessary infrastructures to reach the climate-energy plans' objectives

i. Scenarios for 2020

The aim of this stage is to put in light the required infrastructures to achieve the climate-energy plan's objectives. Concerning objectives 2020, the goal is to reach 2 213 GWh and 2 200 000 teq CO2 GHG emissions. In this part, two scenarios have been created towards these both objectives. Then, two other scenarios have been made up towards objective 2050.

- Scenario 1: we assume the final renewable energies production will be equally reached by the fifth renewable energies we have seen before. This means a 443 GWh production for each renewable resource. The calculations had taken into account the renewable energies production infrastructures that already exist (table 3 in part 3.a). The results are presented just below:

Scenarion 1	BIOMASS	BIOGAS	SOLAR THERMAL	SOLAR PV	WIND TURBINES	TOTAL
Required Infrastructures	**3 biomass centrals as Saint pierre des corps**	**21 biogas cogeneration as Sonzay**	**417 338 m^2**	**Max : 2 053 161 m^2 Min: 1 621 101 m^2**	**172**	
Energy production (GWh)	568	453	443	443,3	444,3	**2 352**
Avoided GHG emissions (teg CO2) by 2020	114 736	91 506	89 486	122 351	122 627	**2 209 294**
Renewable energy's share of final energy consumption						**21,3%**

TABLE 8 SCENARIO 2020 N°1

With this scenario, the renewable energies production reaches 21, 5% of gross energy consumption what is above the initial objective. However, the 20% reduction in GHG emissions by 2020 is not. Indeed, the total emitted GHG emissions by 2020 is 2 209 294 teq CO2 whereas this objective is to obtain 2 202 000 teq CO2 by 2020. To reach both objectives, it is needed to avoid 7 294 teq CO2 more which corresponds to 11 wind turbines production as we have seen in ScOT's renewable energies production by 2020. If we take into account this observation, the scenario would reach 21, 5% renewable energy's share of final energy consumption.

- Scenario 2: we will assume the share of renewable energies production by 2020 would be the same as today. The results are presented below:

Scenarion 2	BIOMASS	BIOGAS	SOLAR THERMAL	SOLAR PV	WIND TURBINES	TOTAL
Required Infrastructures	**15 biomass centrals as Saint pierre des corps**	**21 biogas cogeneration as Sonzay**	**55 303 m^2**	**Max:873 453 Min:676 926**	**1**	
Energy production (GWh)	1678	328	46	142	0,09	**2 647**
Avoided GHG emissions (teg CO_2) by 2020	402 308	84 147	11 730	49 822	31	**2 201 962**
Renewable energy's share of final energy consumption						**23,9%**

TABLE 9: SCENRARIO 2020 N°2

In this scenario, both objectives are also achieved. We can observe that the number of biogas centers is exactly the same as the last scenario. However, in the second scenario, the number of biomass centrals is three times higher than in the first scenario. Concerning wind power, the number of wind turbines is ludicrous in the second scenario, even not developed at all.

ii. Scenarios for 2050

The scenarios 2050 reach the 687 500 teq CO_2 objective. The aim of this part is to put in light what infrastructures would be needed to achieve it.

- Scenario 1: the factor 4 will be reached by the wind turbines production only. To obtain 687 500 teq CO_2 of GHG emissions by 2050, the wind turbines production has to avoid 2 062 500 teq CO_2 of GHG emissions. Which means the wind turbines will have to generate 7 472, 8 GWh. This amount of energy would have to be produced by 2893 wind turbines by 2050.

- Scenario 2: the GHG emissions will be equally reduced by the fifth renewable energies. Which means a avoided GHG emissions equivalent to 412 500 avoided GHG emissions.

c. Comparison analysis between ScOT's projects and the scenarios

This table below summarizes the infrastructures for each calculation. The number of solar panels is the minimum required to reach the objectives with the worse efficiency (0, 15).

	Infrastructures				
	BIOMASS	BIOGAS	SOLAR THERMAL	SOLAR PV	WIND TURBINES
ScOT's renewable energies production by 2020	1	1	180 000	2 652 700 m²	12
Scenario 2020 n°1: the final renewable energies production will be equally reached by the fifth renewable energies	3	21	417 338 m²	1 621 101 m²	183
Scenario 2020 n°2: the share of renewable energies production is the same as today	15	21	55 303 m²	676 926 m²	1
Scenario 2050 n°1:Only wind power development					2 893
Scenario 2 : the GHG emissions will be equally reduced by the fifth renewable energies	16	103	1 944 838 m²	5 604 620 m²	579

TABLE 10: COMPARISON BETWEEN SCOT'S INFRASTRUCTURES AND SCENARIOS

About the renewable energies production based on ScOT's projects, we have to take into account the fact that these projects are thought now but others could come up over the years. The interest of the confrontation between the ScOT's projects and the scenarios is to prove that even if the ScOT foresees others infrastructures in the future to achieve the objectives, it may not be able to do it. In this part, we are not concerned about the budget of the cities or the financial aspects of these infrastructures. The criticism of this study is mainly focused on the ScOT's capacity to host infrastructures within 6 years or 34 years left.

ScOT's projects analysis

We know first that the ScOT's renewable energies production by 2020 may not achieve the objective. What's more, it turns out that some of the identified projects are not likely going to happen by 2020. For example, the solar farm in Larcay is an essential project with a 200 000 m² solar panels installation. This land was an anterior military field and now belongs to the city of Tours. It is written in the ScOT that any fertile land will not be available for the solar panels installation. That's why this project is open to debate and can not be sure to be carried out. About the wind farm, the only area where the wind farm could be set up is in the south of the ScOT territory. It was selected for its wind power potential. It concerns only 2 municipalities: Saint-Branchs and Sorigny. The capacity of these municipalities to host these infrastructures is not a problem. The both are rural and cover 90 km² together. Nevertheless, a wind farm of this capacity requires a long process between 30 or 60 months

(5 years) to be carried out. Indeed, several different kinds of studies have to be made in advance (environmental studies, property development studies…). Today, it does not look like that the process has already started.

Scenarios 2020

About the first scenario 2020, some of the presented infrastructures are possible to carry out. Indeed, in this scenario, the solar PV surface is smaller than the one from the ScOT's projects. What's more, the scenario requires the installation of 3 biomass centrals equivalent to the one installed in Saint Pierre des Corps. The ScOT' has already built one in 2012 in 3 years' time lapse. The two others could definitely emerge over the last 6 years. However, the dimension of the wind farm seems to be blown out of proportion. The number of wind turbines is higher than the number of wind turbines installed in the central region (146 wind turbines are already present in the region). The surface of thermal solar is 100 times higher than the current thermal solar surface which already exists on the territory. This represents a 50% average annual increase. Between 2002 and 2005, the evolution of the solar thermal surface increased by 290% per year. So the solar thermal surface calculated in this scenario may not be as unlikely as it looks like. However, building 21 biogas centrals is ambitious. The ScOT has built one which produces 20GWh in 3 years. If it is the same evolution, the ScOT can build 2 others centrals which are ludicrous compared to the objective.

In the second scenario, the number of wind turbines is the same as today. So in this scenario, the wind power is not developed at all. Concerning solar thermal and solar PV, these two renewable energies are less developed than in the ScOT's projects. The most developed energies are biomass and biogas. The number of required biogas centrals is the same as in the last scenario. However, the number of biomass centrals is 5 times higher than the last scenario. In six years, it is almost impossible to install.

Scenarios 2050

In the first scenario, we have made the hypothesis that the factor 54 will only be achieved by wind power development. The aim of this scenario is to understand what a GHG emissions reduction of 75% by 2050 concretely represents. This scenario points out that an energy production equivalent to 2 893 wind turbines is able to achieve the factor 4. But can it be possible to install? On the ScOT, urbanization covers 200 km² and the forest is spread over 217 km². If we make the hypothesis that the needed floor space to install one wind turbine is about 100 m and it has to be at least 2 km from housing, a wind farm of this proportion requires 23 km². In terms of capacity, these wind turbines can be installed, there is enough land space in the ScOT or in the two municipalities Sorigny and Saint Branchs (that would represents ¼ of their territories). However, by stepping back from this observation, the required number of wind turbines is higher than the number of wind turbines which already exists in France (2 300 wind turbines have been identified in 2010). It would require the ScOT to build 81 wind turbines per year to reach 2 893 wind turbines by 2050. Besides, as we said before, a wind farm project needs 30 months (2, 5 years) or 60 months (5 years) to be carried out. The ScOT is not likely to achieve this number by 2050.

In the second scenario, we have made the same hypothesis as the first scenario 2020 but in terms of GHG emissions. In this case, the number of biomass centrals is quite the same as the one from the second scenario 2020. At least in this scenario, this number may be reached by 2050. However, this scenario suggests the installation of 103 biogas centrals, so 3 installations per year. That may not be possible with the current conditions. The ScoT has built one in three years. Concerning the wind turbines it is the same observation. It requires the installation of 18 wind turbines per year at least to reach the objectives. The ScOT has not built one since 2009.

5. Conclusion

The climate-energy plan is a document which gives orientations to achieve European and national objectives. However, as we have seen in this project, it does not give concrete guidelines to reach these objectives but only some projects in the context of the climate-energy plan. Despite its low renewable energies production in 2009, the ScOT of Tours has an important potential and capacity to host renewable energies infrastructures especially about biomass and biogas energies. However, the study has shown the fact that the ScOT is not likely to handle enough infrastructures by 2020 and 2050 to achieve the objectives. The project had focused on quantification of renewable energies production and the required infrastructures which correspond to this production. But in France, the lack of political will is a factor which explains this observation. As well, some experts suggest that the renewable energies share of final energy consumption will get higher but not necessarily with renewable energies infrastructures. Because of volatile energy prices and new high performance housing, the consumption per inhabitant is going to get lower over the years.

APPENDICES

- Solar PV power simulation according the article : Edward Rajan, S. (2011). *Investigation of cloudless solar radiation with PV module employing Matlab-Simulink*. Solar Energy 85, p 1727-1734

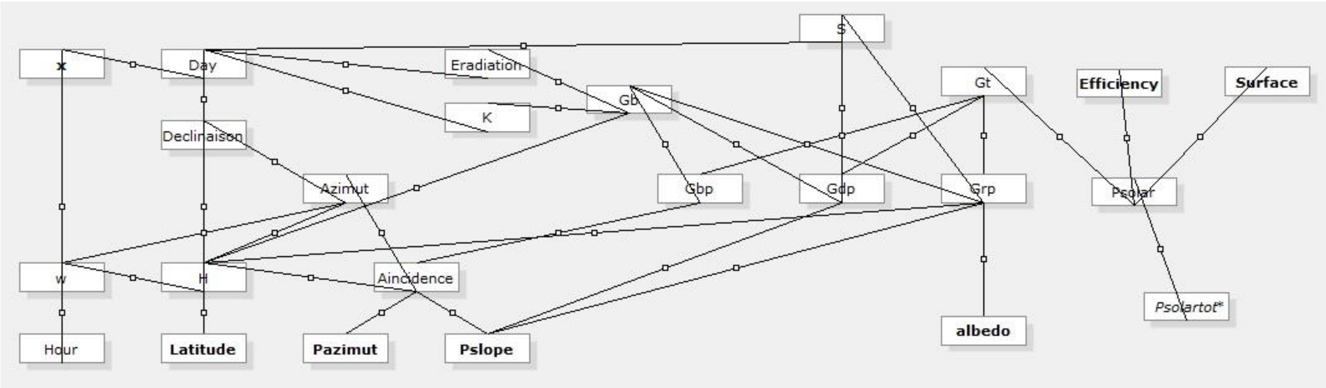

TABLE 11: SOLAR PV POWER SIMULATION INCLUDING CLOUDLESS PARAMETER ON TOASTERSYSTEM (MATLAB)

	Exogenous variables						**Endogenous variable**
Projects	Surface (m²)	Efficiency	Albedo	Pslope (°)	Pazimut (°)	Latitude (°)	Psolartot (GWh/an)
Boulodrome (Tours)	1200	0.15	0.05	30	0	47.25	0,41
	1200	0.19	0.05	30	0	47.25	0,52
Maintenance center (Tram Tours)	1 500	0.15	0.05	30	0	47.25	0,52
	1 500	0.19	0.05	30	0	47.25	0,66
Landfill (Billette)	50 000	0.15	0.05	30	0	47.25	17,25
	50 000	0.19	0.05	30	0	47.25	21,84
Solar farm (Larçay)	200 000	0.15	0.05	30	0	47.22	68,98
	200 000	0.19	0.05	30	0	47.22	87,38
Solar panels	2 400 000	0.15	0.05	30	0	47.25	827,79
	2 400 000	0.19	0.05	30	0	47.25	1 048,54
Total production		0.15					914,95
		0.19					1 158,94

Annual Global irradiation: 2 300 KWh/m²
Min : 0 W/m²
Max : 996.8703 W/m²

- Solar PV simulation with helioclim database 2005

	Exogenous variables						**Endogenous variable**
Projects	Surface (m²)	Efficiency	Albedo	Pslope (°)	Pazimut (°)	Latitude (°)	Psolartot (GWh/an)
Boulodrome (Tours)	1200	0.15	0.05	30	0	47.25	0,25
	1200	0.19	0.05	30	0	47.25	0,32
Maintenance center (Tram Tours)	1 500	0.15	0.05	30	0	47.25	0,31
	1 500	0.19	0.05	30	0	47.25	0,40
Landfill (Billette)	50 000	0.15	0.05	30	0	47.25	10,44
	50 000	0.19	0.05	30	0	47.25	13,22
Solar farm (Larçay)	200 000	0.15	0.05	30	0	47.22	41,76
	200 000	0.19	0.05	30	0	47.22	52,89
Solar panels	2 400 000	0.15	0.05	30	0	47.25	501,09
	2 400 000	0.19	0.05	30	0	47.25	634,72
Total production		0.15					553,86
		0.19					701,55

Annual global irradiation : 1 392 KWh/m²
Min = O W/m²
Max= 996 W/m²

- Wind turbines production

Projects	**Exogenous variables**			**Endogenous variable**		**Cut in speed**	**Cut out speed**
	Air density (kg/m^3)	Swept surface or rotor area (m²)	Wind (m/s)	Windpower (Wh/an)	Windpower (GWh/an)		
12 small wind turbines	1,225	23.5	Min = 0 Max=12,78	99 213 575	0,099	4 m/s	24 m/s
12 wind turbines	1,225	6 644,24	Min = 0 Max=12,78	31 309 928 098	31	3 m/s	24 m/s

Production actuelle du ScOT :

BIOMASS		GEOTHERMAL	
Installations collectives	8	Installations	3
Logements	6 300		
Tonnes bois	32 400	Puissance installée (kW)	225
Production annuelle (Gwh)	**169**	**Production annuelle (GWh)**	**1**
Rejets de CO2 évités (teq CO2/an)	33 740	Rejets CO2 évités (Tco2 /an)	250
BIOGAS		**WIND TURBINES**	
Nb sites	2	Installations	1
		Puissance installée (kW)	5
Production annuelle (Gwh)	**33**	**Production annuelle (Gwh)**	**0,009**
Rejets CO2 évités	6 590	Rejets CO2 évités (teCO2/an)	1,6
SOLAR PV		**HYDROPOWER**	
Installations (dont 15 concernant les collectivités en entreprises)	140	Installations	2
Surface panneaux (m²)	109 671	Puissance installée (kw)	225
Production annuelle (Gwh)	**14,3**	**Production annuelle Gwh**	**1**
Rejets de CO2 évités (teq CO2/an)	2 566	Rejets CO2 évités	170
THERMAL SOLAR		TOTAL	
Installations (150 chauffe-eau solaires individuels, 8 chauffe-eau solaires collectifs, 3 systèmes solaires combinés)	161		
Surface panneaux (m²)	4 379		
Production annuelle (Gwh)	**4,6**	**Production annuelle (Gwh)**	**222,9**
Rejets CO2 évités par an (teq CO2)	1 080	**Rejets CO2 évités (teq CO2/an)**	**44 228**

TABLE 12: INFRASTRUCTURES ET PRODUCTION D'ENERGIE RENOUVELABLE DU SCOT DE TOURS

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ILLUSTRATIONS TABLE

CITERES

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DA5 2013-2014

Titre : La production d'énergie renouvelable dans les plans climat-énergie

Résumé :

La production d'énergies renouvelable est devenue nécessaire pour contrer à la fois les effets du changement climatique et la raréfaction des énergies fossiles dans les années à venir ainsi que l'envolée de leurs prix. Afin de promouvoir leur développement, l'Europe et la France se sont fixées des objectifs concrets aux horizons 2020 concernant les « 3x20% » et aux horizons 2050 concernant le facteur 4. Ces objectifs ont été ensuite déclinés à l'échelle locale dans un document appelé le Plan Climat Energie territorial (PCET) que les communes de plus de 50 000 habitants sont exigées de mettre au point. Ces objectifs sont sujets à de nombreux débats mais aucune étude encore connue n'a véritablement évaluée la faisabilité de ces plans climats et surtout leur capacité à atteindre leurs objectifs. En se focalisant sur le cas du ScOT de Tours et en partant de l'hypothèse que ce territoire ne pourrait pas atteindre les objectifs de son plan climat, il a été nécessaire de quantifier au préalable la production des énergies renouvelables que le ScOT compte aujourd'hui mettre en place. Des scénarios ont été également effectués pour mettre en évidence quelles seraient les infrastructures nécessaires à l'atteinte des objectifs 2020 et 2050 en se basant uniquement sur la production des ENR. Il s'avère qu'en comparant les infrastructures du ScOT et celles des scénarios, que le ScOT ne pourra pas atteindre aux horizons imposés les objectifs du PCET.

Mots Clés : énergie renouvelable, plan climat-énergie