POLITECNICO DI MILANO

FACOLTÀ DI INGEGNERIA CIVILE, AMBIENTALE E TERRITORIALE

Corso di Laurea in Ingegneria per l'Ambiente e il Territorio

ENERGY EFFICIENCY SIMULATOR APPLIED TO REGIONAL RESIDENTIAL BUILDING STOCK IN ALSACE, FRANCE

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ABSTRACT

Keywords: *Energy demand, regional actors, fuel poverty; energy transition*

France is engaged in the climate change problems from various angles: obligations contracted with the Kyoto Protocol are at present under observation, and for this reason efforts are made to reduce its greenhouse gas emissions by 2020, in comparison to the 1990 levels, furthermore, it is engaged in the Climate and Energy package adopted by the European Union and the European Parliament in December 2008[1]. These engagements, that have been formalized according to the Climate Plan in 2004 at national level, and actualized in 2006, have been the central argument within the "*Grenelle de l'environnement*" discussions. In order to be effective, all actions issued during such discussions can only be started if all the involved actors and all the regions contribute actively.

All regions have taken their part in the fight against climate changes, regional climate and energy package, having defined four main strategy axes: reduction in greenhouse gas emissions and energy demand; prevention of and reduction in atmospheric pollution; development of renewable energy production; regional synergies among climate, air and energy.

The aim of this study is to analyze and understand the evolution of the residential building stock features at regional level, as well as the actions connected with the political decisions: renewable energy production, changes in energy mix, and renewals in the building practices.

Within the framework of regional perspective, the goal is to obtain the expected results by applying some hypotheses: the optimal solution, which best fits in the final goal, is studied through the different scenario analyses.

The "Factor 4" scenario, preferred by the international politics, is achieved through global efforts and different actions: energy, energy efficiency, most effective and efficient technologies, best management for consumptions and decentralized production of renewable energy.

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[1] Directive 2009/28/CE

RÉSUME

Mots-clés: *Demande en énergie, Entité régionales, Précarité énergétique, Transition énergétique*

La France est engagée dans la lutte contre le changement climatique à plusieurs titres : elle veille à respecter rigoureusement les obligations qu'elle a contractées au titre du Protocole de Kyoto et à ce titre stabilisera ses émissions de gaz à effet de serre au niveau de 1990 à l'horizon 2020. Elle s'y est engagée, dans le cadre du paquet énergie climat adopté par le Conseil de l'Union européenne et le Parlement européen en décembre 2008[2]. Ces engagements, formalisés à l'échelle nationale par le Plan Climat lancé en 2004 et actualisé en 2006, ont été au centre des discussions du Grenelle de l'environnement. Ils ne pourront être tenus, et les actions issues du Grenelle ne pourront être lancées qu'avec les efforts conjugués de l'ensemble des acteurs et la mobilisation des territoires.

Les territoires ont pris part à la lutte contre le changement climatique et dans les plans climat énergie territoriaux ; ils ont défini cinq axes stratégiques : la réduction des émissions de gaz à effet de serre et la maîtrise de la demande énergétique ; la prévention et la réduction de la pollution atmosphérique ; le développement de la production d'énergies renouvelables ; les synergies du territoire en matière de climat-air-énergie.[3]

La présente étude s'attache à analyser et à comprendre d'une part les évolutions du parc résidentiel à l'échelle territoriale et d'autre part les actions associées aux décisions de politique énergétique : l'intégration des énergies renouvelables, des technologies performantes, les changements des mix énergétiques, les rénovations des bâtiments. Dans le cadre de la recherche à un échelon territorial, on définit des jeux d'hypothèses locales qui ont permis d'arriver aux résultats souhaités. En procédant à une étude des différents scénarios, nous examinons, via un simulateur dédié, les solutions optimales pour atteindre les cibles espérées en matière de mix énergétique, d'émissions de CO_2, d'investissements consentis, d'emplois directs et indirects générés et enfin de facture énergétiques des ménages.

Le scenario 'Facteur 4 volontariste', objectif des politiques internationales, ne peut être atteint que par la combinaison d'efforts financiers globaux conséquents et par des actions distinctes et massives touchant à l'efficacité énergétique du bâti et des systèmes, à la production décentralisée autoconsommée via l'usage des énergies renouvelables et enfin à la sobriété énergétique. Le résultat du scénario Facteur 4 peut ainsi être obtenu grâce à la rénovation du bâti, avec les technologies les plus efficaces et avec un comportement adapté pour une meilleure gestion des consommations. L'ensemble du scénario 'Facteur 4' en Alsace nécessite malgré tout un effort financier multiplié par un facteur de 6,6 par rapport au scénario tendanciel à 2050.

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[2] Directive 2009/28/CE du parlement européen

[3] Ministère de l'Écologie, de l'Énergie, du Développement durable et de la Mer, en charge des Technologies vertes et des Négociations, Plans Climat-énergie territoriaux, mai 2009.

RIASSUNTO

Parole chiave: *Domanda di energia; entità regionali; precarietà energetica; transizione energetica.*

La Francia è occupata contro i problemi dei cambiamenti climatici in diversi aspetti: deve rispettare le obbligazioni connesse col Protocollo di Kyoto e rispettare il pacchetto Clima Energia adottato dalla Commissione Europea e dal Parlamento nel dicembre 2008[4]. Questi impegni, formalizzati col Piano Energia nel 2004 a scala nazionale e attualizzati nel 2006, hanno un ruolo centrale nelle discussioni di "*Granelle de l'environnement*"; tutte queste azioni emesse durante molteplici discussioni ed accordi possono essere attuate solamente grazie al coinvolgimento di diversi attori e delle regioni per una loro attiva collaborazione.

Tutte le regioni francesi hanno preso parte alla lotta contro i cambiamenti climatici e nel pacchetto clima ed energia regionale sono state definite quattro strategie principali: la riduzione dei gas a effetto serra e della domanda di energia; la prevenzione e la riduzione dell' inquinamento atmosferico; lo sviluppo della produzione di energia da parte di fonti rinnovabili e sinergia regionale tra clima, aria ed energia.

L' obiettivo di questo studio è l'analisi e la comprensione delle evoluzioni del parco residenziale a scala regionale e delle azioni connesse con le decisioni politiche inerenti: la produzione di energie rinnovabili, il cambiamento del mix energetico, il rinnovamento delle abitazioni. In un contesto di prospettiva regionale l'obiettivo è di ottenere risultati auspicati, attraverso diverse ipotesi: una soluzione ottimale è raggiunta con l'analisi di diversi scenari.

È stato sviluppato un simulatore di Efficienza Energetica sul parco regionale residenziale, per sostenere ed accompagnare le politiche locali sui temi di sviluppo sostenibile ed efficienza energetica. Questo studio è stato sviluppato nel contesto dei "*Grands Programmes Regionaux*" del dipartimento di Ricerca e Sviluppo di EDF. Esso si basa su una simulazione prospettica al orizzonte 2030-2050.

In prima istanza sono state analizzate le politiche europee e nazionali Francesi riguardanti politiche di gestione dell'energia e dell'ambiente, con particolare attenzione al pacchetto 20-20-20 ed alle direttive di performance energetica sugli edifici[5]. Presentando in seguito la situazione Francese ed Italiana, è stato evidenziato il forte peso del settore residenziale sui consumi di energia finale, e la necessità di agire a medio e lungo termine per assicurarsi una maggior efficienza e riduzione dei consumi.

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[4] EU climate and energy package (20-20-20)

[5] Directive 2002/91/EC on Energy Performance of Buildings

Sono stati quindi analizzati i modelli e metodi presenti in letteratura applicati al settore residenziale, utili in particolare per valutare il contributo di politiche climatiche ex-ante e ex-post. Non esiste in letteratura una metodologia standardizzata, poiché esistono differenti fattori da tenere in considerazione: la scala di dettaglio (nazionale, regionale, puntuale..), l'orizzonte temporale (breve, medio e lungo termine) e le leve che possono influenzare i comportamenti del sistema (orientamenti politici, comportamenti …).

Un altro aspetto considerato ed analizzato è la valutazione di politiche attraverso la "metodologia degli scenari", molto diffusa in tutte le politiche internazionale e presso enti scientifici per valutare le possibili condizioni future date da cambiamenti politici, energetici, tecnologici e comportamentali.

In seguito a questa prima analisi e contestualizzazione generale del lavoro, è presentata la regione studio della ricerca: l'Alsazia. Questa è una piccola ma dinamica regione nel nord-est francese che è stata una delle regioni pilota in materia di energie rinnovabili e sviluppo di case a basso consumo energetico. Essa ha iniziato una politica di sviluppo sostenibile attraverso la collaborazione di diversi enti nazionale (ADEME; EDF…).

In collaborazione con la regione Alsazia è stato dunque sviluppato il Simulatore di Efficienza Energetica che si prefigge di essere un aiuto alle decisioni politiche e strumento di sensibilizzazione sui principali problemi energetici. Lo sviluppo e creazione del simulatore è suddiviso in tre parti: lo sviluppo dello strumento di calcolo, la creazione dell'interfaccia grafica e della procedura informatica. Lo strumento di calcolo è il cuore di calcolo che permette, per una serie di dati in ingresso, di restituire i risultati desiderati; l'interfaccia grafica è la parte che permette un interazione con l'utente e la scelta di possibili azioni che andranno ad alimentare parte della famiglia dei dati d'ingrasso.

Tenendo in considerazione che le azioni per una drastica riduzione del consumo energetico sono fondamentalmente quattro (cambiamenti comportamentali, efficienza energetica attraverso rinnovo degli edifici, tecnologie più efficienti e produzione decentralizzata di energia attraverso fonti rinnovabili), sono stati sviluppati due tipi di simulazione: una basata su scelte manuali sulle azioni da mettere in atto ed una seconda basata su scenari prestabiliti, finalizzati a ottenere target desiderati.

Le azioni su cui l'utente può agire sono: il livello di isolamento degli edifici, i mix energetici e le tecnologie per gli usi d riscaldamento e acqua calda domestica, l'utilizzo di energie rinnovabili (fotovoltaico e micro eolico) e la temperatura interna degli edifici.

Gli scenari che sono stati sviluppati sono stati: Scenario Tendenziale, Scenario No Fuel, (si prefigge una soppressione di combustibile al orizzonte 2050, privilegiando la biomassa locale), Scenario Energie Rinnovabili (incorpora una politica di forte attenzione all'utilizzo di energie rinnovabili distribuite e uno sviluppo di tecnologie performanti), e Scenario Fattore 4 (incorpora un rinnovo del parco residenziale per una miglior isolamento, riduzione importante di combustibili fossili, sistemi più performanti ed utilizzo di energie rinnovabili).

Il modello sviluppato è di tipo bottom-up, un modello che necessita una grande quantità di dati disaggregati di input da interconnettere e calcolare i parametri di uscita desiderati. I dati di ingresso sono stati divisi in tre grandi famiglie: i dati statistici regionali, le ipotesi "invariabili" e "variabili". La prima famiglia di ipotesi sono delle ipotesi date da esperti o calcolate ex ante con dei modelli; alle ipotesi variabili invece appartengono tutte quelle variabili che possono assumere valori diversi per ogni scenario oppure le azioni su cui l'utente può agire. In seguito si riporta una tabelle che riassume le diverse categorie di dati d'ingresso del simulatore.

Figure 1: Dati in ingrasso al simulatore

DATI IN INGRESSO

Popolazione	
Suddivisione parco esistente	Tipo di abitazione, periodo di costruzione, energia utilizzata
Fabbisogni	Riscaldamento, Acqua calda domestica
Area Climatica	Irradiazione solare, Intensità del vento
Ipotesi Invariabili	Evoluzione rendimento dei sistemi, evoluzione dei fabbisogni, prezzo dell'energia…
Ipotesi Variabili	Livello di isolamento, suddivisione energetica e tecnologica, tasso di rinnovo del parco, penetrazione EnR, temperatura interna abitazioni

I dati di uscita del modello sono in parte energetico-ambientali ed in parte socio-economici: i consumi di energia finale, le emissioni di $CO_{2,}$, gli investimenti totali, il lavoro aggiunto e la fattura energetica.

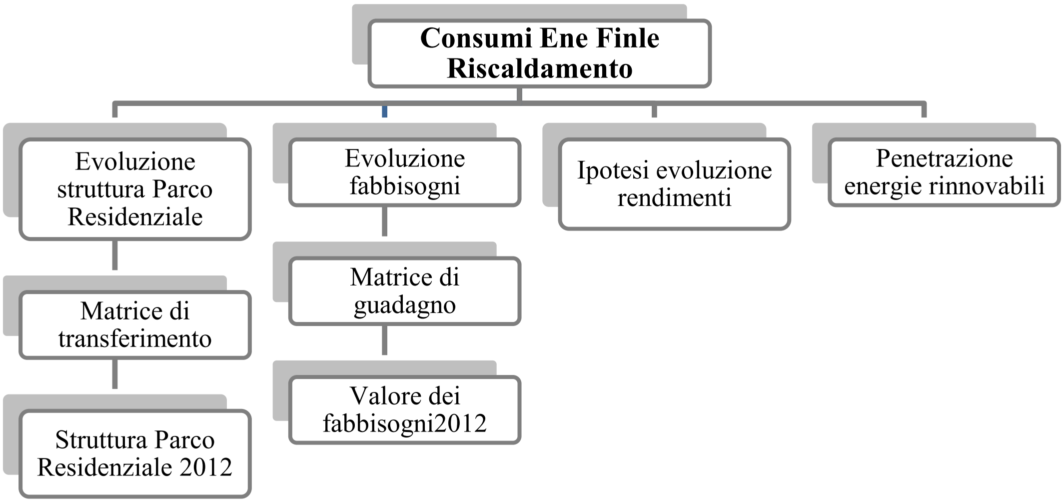
Tutti i calcoli sono stati fatti partendo dal parco residenziale regionale diviso i quattro periodi di costruzione (periodi che corrispondono alle principali norme di regolamentazione termica) e analizzando cinque usi energetici (riscaldamento, acqua calda sanitaria, climatizzazione, cucina e elettricità specifica). Gli usi di climatizzazione, cucina e elettricità specifica, avendo un ruolo marginale, sono stati trattati in maniera semplificativa.

Analizzando il sistema di riscaldamento, che copre il 73% di consumi di energia finale in Alsazia, sono stati stimati i fabbisogni di energia finale per l'anno di riferimento. Ogni classe di costruzione è stata suddivisa in efficace e non efficace, per tener conto delle variazioni di dati disponibili di fabbisogni, questi hanno una grande varianza per i lavori di rinnovo già attuati nelle abitazioni, i cambiamenti tecnologici …

Sono state costruite in seguito due matrici: una matrice di trasferimento, che dipende da cambiamenti di energia, tecnologie e classe di efficienza; e una matrice di guadagno sui valori dei bisogni, che dipende dalle misure di rinnovo e dalla temperatura interiore degli edifici. Tutti questi fattori rappresentano la famiglia di azioni sceglibile dall'utente.

Quindi per calcolare i consumi di energia finale per uso riscaldamento domestico, si parte dalla situazione del parco residenziale all'anno t_0 (in termini di numero di abitazione per energia, tecnologia, e classe di efficienza), a questo si applica la matrice di trasferimento, per avere la nuova struttura del parco all'istante $t_0+\Delta t$. In seguito partendo dai valori dei bisogni all' istante t_0 si calcola l'evoluzione dei bisogni attraverso la matrice dei guadagni. I consumi per periodo di costruzione del parco sono stimati attraverso la nuova struttura del parco all'istante $t_0+\Delta t$., i bisogni $t_0+\Delta t$ e l'ipotesi dell'evoluzione dei rendimenti dei sistemi. A questi consumi è sottratta la parte di produzione di energie rinnovabili decentralizzate, che sono state considerate come un fattore esogeno. Lo schema base del calcolo è riportato in seguito. La produzione di CO_2 è calcolata sulla base dei consumi di energia finale e dei coefficienti di emissioni.

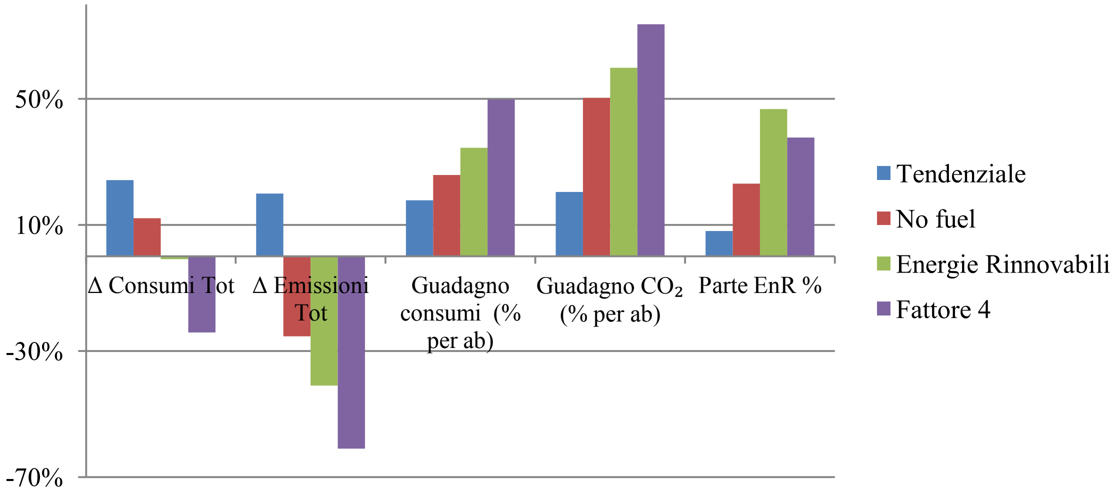
Figure 2: Schema di calcolo per i consumi di energia finale per riscaldamento domestico



Infine la valutazione dei risultati e l'analisi di sensibilità è stata fatta sulla base degli scenari prestabiliti.

Un analisi significativa è la comparazione dei risultatati aggregati per i quattro scenari, che permette di dare un ordine di grandezza e un orientamento delle possibili azioni da mettere in atto. Si riportano in seguito i principali risultati.

Figure 3: Principali risultati aggregati per i quattro scenari in analisi.



I risultati più rilevanti sono: lo scenario No Fuel permette una riduzione drastica delle emissioni di CO_2 con investimenti accessibili, lo scenario Energie Rinnovabili è vantaggioso sia per la riduzione delle consumazioni sia per le emissioni, ma è economicamente più difficile da attuare per i forti costi d'investimento. Lo scenario ambito è il Fattore 4.

Un fattore da rimarcare è che per arrivare allo scenario "Fattore 4", è necessario mettere in atto una serie di diverse azioni: rinnovo degli edifici, cambiamenti di energie utilizzate, tecnologie più performanti e incremento dell'utilizzo di energie rinnovabili. Una sola di queste azioni non è sufficiente per arrivare ai target prefissati.

Infine l'analisi di sensibilità di diverse variazioni allo scenario Tendenziale ha permesso di mettere in evidenza quali sono i parametri che influenzano maggiormente la riduzione dei consumi e delle emissioni di CO_2.

Gli studi su diversi scenari ha permesso di valutare le possibili strategie. I risultati ottenuti sono a volte economicamente o socialmente irrealizzabili ma possono dare elementi di conoscenza e riflessione alle autorità regionali per migliorare il futuro energetico.

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INTRODUCTION

Fight against the climate change, energy economy, development of renewable energies and increase in air quality are some of the actual and important themes nowadays.

In order to contribute to a suitable development towards the energy efficiency, and to help the regional collectivities, the EDF group is developing a special tool for helping the decision makers. This study has been developed within this context by the EDF R&D department.

Such a study is aiming at creating an Energy Efficiency simulator within the residential building stock on a regional scale, at the time horizon 2030-2050. The first is focusing more on the analysis concerning the European, French and Italian energy and environmental politics, introducing at the same time the Alsatian situation, which is the context region of the study, where concentration is placed on a physical and energetic description of the region, issues connected with the exploitation of local resources, CO_2 emissions and local employment.

Another chapter is based on the literature review about the methodology of building stock modeling, where the "bottom up" and "top down" methods are being focused; as well as the scenario methodology, that is, a complementary approach for the evaluation of climate policies.

The fourth chapter is focusing on the presentation of the energy efficiency simulator, its aims and objectives, as well as its development methodology. Another one chapter is explaining then the methodology of calculus, the data input analyzed, the hypothesis, the creation of four scenarios and the possesses of calculus in order to obtaining the wished results for the different uses (heating, hot water, air conditioning…).

The last chapter is focusing instead on the analysis of the results and on the sensitivity analysis, referred to the Baseline scenario. Finally, the last chapter is reporting the main conclusions of this study and the wished prospective.

1.

THE EUROPEAN CLIMATE ACTION

1. The climate change

The changes our planet has undergone throughout its history are a result of natural factors, such as tiny changes in the Earth's path around the sun, volcanic activity and fluctuations within the climate system. However, humans are having an increasing influence on our climate by burning fossil fuels, cutting down rainforests and farming livestock.

As the sun's energy warms up the Earth, our planet radiates some of this heat back out towards space. Certain gases in the atmosphere act like glasses in a greenhouse, allowing the sun's energy in, but preventing heat from escaping. Some greenhouse gases (GHG), such as water vapor - the most abundant greenhouse gas - are naturally present in the atmosphere; without them, the Earth's average temperature would be an unbearably cold -18ºC instead of the 15ºC it is today. However, human activities are releasing immense additional amounts of greenhouse gases into the atmosphere, enhancing the greenhouse effect and warming the climate.

The greenhouse gas most commonly produced by human activities is carbon dioxide (CO_2). It is responsible for some 63% of man-made global warming. One of the main sources of CO_2 in the atmosphere is the combustion of fossil fuels - coal, oil and gas. Over the past couple of centuries, our societies have burnt increasing amounts of fossil fuels to power machines, generate electricity, heat buildings and transport people and goods. Since the Industrial Revolution the concentration of CO_2 in the atmosphere has increased by around 41%, and it continues to rise.

Trees help to regulate the climate by absorb CO_2 from the atmosphere, and immense amounts of carbon are stored in the world's forests. When forests are cut down, the carbon stored in the trees is released into the atmosphere as CO_2, adding to the greenhouse effect. On top of that, when a forest is destroyed, it can no longer absorb CO_2 from the atmosphere.

Other greenhouse gases are emitted in smaller quantities than CO_2. However, they all trap heat far more effectively than CO_2 does, in some cases by a factor of thousands of times, making them also powerful contributors to global warming. In addition to CO_2, five other gases are controlled by the Kyoto Protocol, the international treaty which sets limitations on greenhouse gas emissions from developed countries. These gases are: methane (CH_4), nitrous oxide (N_2O), sulphur hexafluoride (SF_6), hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs).

1.1. What is the EU doing about climate change?

Preventing dangerous climate change is a strategic priority for the European Union. Europe is working hard to cut its greenhouse gas emissions substantially, while encouraging other nations and regions to do likewise. In parallel, the European Commission and some Member States are developing adaptation strategies to help strengthen Europe's resilience to the inevitable impacts of climate change. Reining in climate change carries a cost, but doing nothing would be far more expensive in the long run. Moreover, investing in the green technologies that cut emissions will also boost the economy, create jobs and strengthen Europe's competitiveness.

To prevent the most severe impacts of climate change, the international community has agreed that global warming should be kept below 2ºC compared to the temperature in pre-industrial times. That means a temperature increase of no more than 1.2°C above today's level. To stay within this ceiling, the scientific evidence shows that the world must stop the growth in global greenhouse gas emissions by 2020 at the latest, reduce them by at least half of 1990 levels by the middle of this century, and continue cutting them thereafter.

EU leaders have committed to transforming Europe into a highly energy-efficient, low carbon economy. The EU has set itself targets for reducing its greenhouse gas emissions progressively up to 2050 and is working successfully towards meeting them.

Under the Kyoto Protocol, the 15 countries that were EU members before 2004 ('EU-15') are committed to reduce their collective emissions to 8% below 1990 levels by the years **2008-2012**. Emissions monitoring and projections show that the EU-15 is well on track to meet this target. Most Member States that have joined the EU since 2004 also have Kyoto reduction targets of 6% or 8% which they are on course to achieve.

By **2020**, the EU has committed to cut its emissions to 20% below 1990 levels. This commitment is one of the headline targets of the Europe 2020 growth strategy, and is being implemented through a package of binding legislation[1]. The EU has offered to increase its emissions reduction to 30% by 2020, if other major emitting countries in the developed and developing worlds, commit to undertake their fair share of a global emissions reduction effort.

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[1] Speech by President Barroso at the European Parliament Plenary session, 12 September 2012

By **2050**, EU leaders have endorsed the objective of reducing greenhouse gas emissions in Europe by 80-95%, compared to 1990 levels, as part of the efforts by developed countries, as a group, in order to reduce their emissions by a similar degree. The European Commission has published a roadmap for buildings showing the low-carbon European economy[2] that this will require.

2. EU initiatives

EU initiatives to reduce greenhouse gas emissions include:

- The European Climate Change Programme (ECCP), which has led to the implementation of dozens of new policies and measures;
- The EU Emissions Trading System, which has become the EU's key tool for reducing greenhouse gas emissions from industry most cost-effectively[3];
- Adopting legislation to raise the share of energy consumption produced by renewable energy sources, such as wind, solar and biomass, to 20% by 2020;
- Setting a target to increase Europe's energy efficiency by 20% by 2020, though improving the energy efficiency for buildings and for a wide array of equipment and household appliances;
- Binding targets to reduce CO_2 emissions from new cars and vans[4];
- Supporting the development of carbon capture and storage (CCS) technologies[5] to trap and store CO_2 emitted by power stations and other major industrial installations.

The fight against climate change is increasingly being reflected in other policy areas, as well. To further advance this "mainstreaming" process, the European Commission has proposed that at least 20% of the EU's budget for 2014-2020 should be spent on climate-relevant measures.

The EU has long been a driving force for the international negotiations on climate change, and been instrumental in the development of the UN Framework Convention on Climate Change (UNFCCC), and the Kyoto Protocol.

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[2] COM (2011) 112: A Roadmap for moving towards a competitive low carbon economy in 2050 (08 March 2011)

[3] The EU Emissions Trading System (EU ETS) is a cornerstone of the European Union's policy to combat climate change and its key tool for reducing industrial greenhouse gas emissions cost-effectively. Being the first and biggest international scheme for the trading of greenhouse gas emission allowances, the EU ETS covers some 11,000 power stations and industrial plants in 30 countries. http://ec.europa.eu/clima/policies/ets/documentation_en.htm

[4] Transport is responsible for around a quarter of EU greenhouse gas emissions making it the second biggest greenhouse gas emitting sector after energy. http://ec.europa.eu/clima/policies/transport/index_en.htm

[5] Directive 2009/31/EC of the European Parliament and of the Council of 23 April 2009 on the geological storage of carbon dioxide and amending Council Directive 85/337/EEC.

Carbon capture and geological storage (CCS) is a technique for trapping carbon dioxide as it is emitted from large point sources, compressing it, and transporting it to a suitable storage site, where it is injected into the ground. The technology of carbon capture and storage has significant potential as a mitigation technique for climate change, both within Europe and internationally, as well, particularly in those countries having large reserves of fossil fuels and a fast-increasing energy demand. In the EU the CO_2 emissions avoided through CCS in 2030 could account for some 15% of the reductions required.

Thanks to pressure from the EU and other progressive countries, UN negotiations are under way to draw up a new global climate agreement covering all countries, and to achieve greater cuts in global emissions over the rest of this decade. The aim is to keep global warming below 2°C compared to the temperature that prevailed in pre-industrial times.

The new framework is to be finalized by 2015 and implemented from 2020. The EU is pressing for an agreement that is ambitious, comprehensive and legally binding. Pending On its entry into force, the EU will take part, in a second phase of the Kyoto Protocol, starting on 1st January 2013.

3. The EU climate and energy package (20-20-20)

The climate and energy package is a set of binding legislations, which aims to ensure the European Union meets its ambitious climate and energy targets by 2020.

These targets, known as the "20-20-20" targets, set three key objectives for 2020:

- A 20% reduction in EU greenhouse gas emissions from 1990 levels;
- Raising the share of EU energy consumption produced from renewable resources to 20%;
- A 20% improvement in the EU's energy efficiency.

The targets were set by EU leaders in March 2007, when they committed Europe to become a highly energy-efficient, low carbon economy, and were enacted through the climate and energy package in 2009. The EU is also offering to increase its emissions reduction to 30% by 2020 if other major economies in the developed and developing worlds commit to undertake their fair share of a global emissions reduction effort. The European Commission has published a Communication[6] analyzing the options for moving beyond a 20% reduction by 2020 and assessing the risk of "carbon leakage[7]".

The 20-20-20 targets represent an integrated approach to climate and energy policy that aims to combat climate change, increase the EU's energy security and strengthen its competitiveness. They are also headline targets of the Europe 2020 strategy for smart, sustainable and inclusive growth. This reflects the recognition that, by tackling the climate and energy challenge, it will contribute to the creation of jobs, the generation of "green" growth and a strengthening of Europe's competitiveness. It is estimated that meeting the 20% renewable energy target could have a net effect of creating around 417

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[6] EU, communication from the commission to the European parliament, the council, the European economic and social committee and the committee of the regions

[7] Carbon leakage is the term often used to describe the situation that may occur if, for reasons of costs related to climate policies, businesses were to transfer production to other countries which have laxer constraints on greenhouse gas emissions. This could lead to an increase in their total emissions.

000 additional jobs, while getting on track to achieve the 20% energy efficiency improvement in 2020 is forecast to boost a net employment by some 400 000 jobs[8].

The climate and energy package comprises four pieces of complementary legislation which are intended to deliver on the 20-20-20 targets:

I. Reform of the EU Emissions Trading System (EU ETS)

The EU ETS[9] is the key tool for cutting industrial greenhouse gas emissions most cost-effectively. The climate and energy package includes a comprehensive revision and strengthening of the legislation which underpins the EU ETS, the Emissions Trading Directive[10]

The revision applies from 2013, the start of the third trading period of the EU ETS. Major changes include the introduction of a single EU-wide cap on emission allowances in place of the existing system of national caps. The cap will be cut each year so that by 2020 emissions will be 21% below the 2005 level. The free allocation of allowances will be progressively replaced by auctioning[11], starting with the power sector. The power sectors and the types of gases covered by the system will be slightly widened.

II. National Target for non-EU ETS émissions

Under the so-called Effort Sharing Decision, Member States have taken on binding annual targets for reducing their greenhouse gas emissions from the sectors not covered by the EU ETS, such as housing, agriculture, waste and transport (excluding aviation). Around 60% of the EU's total emissions come from sectors outside the EU ETS.

The national targets[12], covering the period 2013-2020, are differentiated according to Member States' relative wealth. They range from a 20% emissions reduction (compared to 2005) by the richest Member States to a 20% increase by the least wealthy (though this

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[8] Esteemed from European Commission , Climate Action, Policies , Climate and energy package

[9] The EU Emissions Trading System (EU ETS) is a cornerstone of the European Union's policy to combat climate change and its key tool for reducing industrial greenhouse gas emissions cost-effectively. Being the first and biggest international scheme for the trading of greenhouse gas emission allowances, the EU ETS covers some 11,000 power stations and industrial plants in 30 countries.

[10] Directive 2003/87/EC of the European Parliament and of the Council of 13 October 2003 establishing a scheme for greenhouse gas emission allowance trading within the Community and amending Council Directive 96/61/EC (Text with EEA relevance)

[11] During the first trading period (2005 to 2007), Member States have auctioned only very limited quantities of carbon allowances, and also during the second trading period (2008 to 2012) the lion's share of carbon allowances is still allocated for free. From the start of the third trading period in 2013, about half of the allowances are expected to be auctioned. Auctioning is the most transparent allocation method that allows market participants to acquire the allowances concerned at the market price.

[12] Directive 2009/29/EC

will still requires a limitation effort by all countries). Member States must report on their emissions annually under the EU monitoring mechanism[13].

III. National renewable energy targets

Under the Renewable Energy Directive[14], Member States have taken on binding national targets for raising the share of renewable energy in their energy consumption by 2020. These targets, which reflect Member States' different starting points and potential for increasing renewables production, range from 10% in Malta to 49% in Sweden.

The national targets will enable the EU, as a whole, to reach its 20% renewable energy target by 2020 - more than double the 2010 level, of 9.8% - as well as a 10% share of renewable energy in the transport sector. The targets will also help to cut greenhouse gas emissions and reduce the EU’s dependence on imported energy.

IV. Carbon capture and storage

The fourth element of the climate and energy package is a directive creating a legal framework[15] for the environmentally safe use of carbon capture and storage technologies. Carbon capture and storage involves capturing the carbon dioxide emitted by industrial processes and storing it in underground geological formations, where it does not contribute to global warming.

The directive covers all CO_2 storage in geological formations in the EU and lays down requirements which apply to the entire lifetime of storage sites. The climate and energy package does not address the energy efficiency target directly. This is being done through the 2011 Energy Efficiency Plan and the Energy Efficiency Directive[16].

4. Roadmap for moving to a low-carbon economy in 2050

The European Commission is looking at cost-efficient ways to make the European economy more climate-friendly and less energy-consuming. By 2050, Europe could cut most of its greenhouse gas emissions. Clean technologies are the future for Europe's economy.

If the EU makes the transition to a low-carbon society by 2050 we will live and work in low-energy and low-emission buildings, with intelligent heating and cooling systems. We

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[13] 25 April 2002 - 2002/358/CE - Council Decision concerning the approval, on behalf of the European Community, of the Kyoto Protocol to the United Nations Framework Convention on Climate Change and the joint fulfilment of commitments thereunder

[14] Directive 2009/28/EC of 23 April 2009 on the promotion of the use of energy from renewable sources and amending, and subsequently repealing Directives 2001/77/EC and 2003/30/EC

[15] Annual European Union greenhouse gas inventory 1990–2010 and inventory report 2012 (European Environment Agency)

[16] COM/2011/0109 final, Communication from the commission to the European parliament, the council, the European economic and social committee and the committee of the regions energy efficiency plan 2011

will drive electric and hybrid cars and live in cleaner cities with less air pollution and better public transport. The transition would give Europe's economy a boost, thanks to increased investment in clean technologies and clean energy. Europe could cut most of its emissions and reduce its use of key resources, like oil and gas, raw materials, land and water.

4.1. Green growth & jobs

A low-carbon economy would have a much greater need for renewable sources of energy, energy-efficient building materials, hybrid and electric cars, 'smart grid' equipment, low-carbon power generation and carbon capture and storage technologies.

To make the transition to a low-carbon economy and to reap its benefits, such as a lower oil bill, the EU would need to invest an additional €270 billion or 1.5% of its GDP annually, on average, over the next four decades. The extra investments will bring us back to investment levels since before the economic crisis, and will spur growth within a wide range of manufacturing sectors and environmental services in Europe. By stepping up climate action 1.5 million additional jobs could be created by 2020.

4.2. Saving energy

The key driver for this transition will be energy efficiency. By 2050, the energy sector, households and business could reduce their energy consumption by around 30% compared to 2005, while enjoying more and better energy services at the same time.

More locally produced energy would be used, mostly from renewable sources. As a result, the EU would be less dependent on expensive imports of oil and gas from outside the EU, and our economies would be less vulnerable to increasing oil prices. On average, the EU could save € 175 - 320 billion annually on fuel costs over the next forty years.

The transition to clean technologies and electric cars will drastically reduce air pollution in European cities. Fewer people would suffer from asthma and other respiratory diseases; considerably less money would need to be spent on health care and on equipment to control air pollution. By 2050, the EU could save up to 88 billion a year.

5. European Climate Change Programme (ECCP)

The European Union has been long time committed to international efforts to tackle climate change and felt the duty to set an example through robust policy-making at home. At European level, a comprehensive package of policy measures to reduce greenhouse gas emissions has been initiated through the European Climate Change Programme (ECCP). Each of the EU Member States has also put in place its own domestic actions that build on the ECCP measures or complement them.

The European Commission has taken many climate-related initiatives since 1991, when it issued the first Community strategy to limit carbon dioxide (CO_2) emissions and improve energy efficiency. These include: a directive to promote electricity from renewable energy, voluntary commitments by car makers to reduce CO_2 emissions by 25% and proposals on the taxation of energy products.

However, it is clear that action by both Member States and the European Community needs to be reinforced if the EU is to succeed in cutting its greenhouse gas emissions to 8% below 1990 levels by 2008-2012, as required by the Kyoto Protocol.

The EU Council of Environment Ministers acknowledged the importance of taking further steps at Community level by asking the Commission to put forward a list of priority actions and policy measures.

The Commission responded in June 2000 by launching the European Climate Change Programme (ECCP). The goal of the ECCP is to identify and develop all the necessary elements of an EU strategy to implement the Kyoto Protocol.

The development of the first ECCP (2000-2004) involved all the relevant groups of stakeholders working together, including representatives from the Commission's different departments (DGs), the Member States, industry and environmental groups. The second European Climate Change Programme (ECCP II) was launched on October 2005.

A key component of the ECCP was the identification of cost effective additional measures to help the EU meeting its Kyoto Protocol target. These are known as common and coordinated policies and measures (CCPMs)[17].

The first ECCP reviewed over 40 measures for their potential contribution to the Kyoto target. The programme estimated that a number of cost-effective options had a technical potential‘ to achieve savings of between 664 and 765 Mt CO^2eq in 2010 (average of emissions between 2008 and 2012). Put in context, 765 Mt CO^2 is equivalent to 14% of the base-year emissions[18] reported for the EU-27 as a whole (based on data available from national greenhouse gas inventories as of 18 June 2008[19]). A number of measures were identified across a range of sectors and included, for example, proposals for an EU ETS, EPBD, biofuels directive, energy efficient public procurement, and revision of the IPPC directive.

In 2005, the European Commission launched the second European Climate Change Programme (ECCP II), establishing a number of stakeholder working groups to review ECCP.1 Progress and investigate new policy areas.

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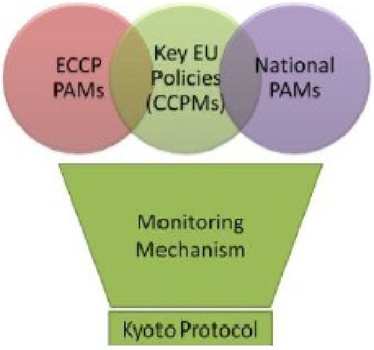
[17] CCPMs are policies and measures developed by the European Union that apply across Europe, as described in the 3rd National Communication of the EU to the UNFCCC in November 2001. The ECCP is the main (but not only) source of CCPMs that have an impact on GHG emissions, so that the EU-level directives and regulations included in the ECCP PAMs are a subset of those classified as CCPMs.

[18] Cyprus and Malta and EU-27 do not have targets under the Kyoto Protocol and, as such, they do not have applicable Kyoto Protocol base years. Therefore 1990 data have been used for these two countries.

[19] EEA, (2008), Annual European Community greenhouse gas inventory 1990 - 2006 and inventory report 2008, EEA Report No. 6/2008.

In addition to CCPMs implemented by or strengthened through MS policies, many Member States have specific national policies and measures in place, which are not directly related to the EU initiatives. The linkage between the ECCP, between CCPMs and between national climate change policies is illustrated in the figure below. (D. Forster, et al., 2009)

Figure 1.1: Illustration of the overlaps between climate change policies at EU and national level



5.1. Policies drivers

Several studies are carried on ex-post impacts, i.e. the impacts of policies and measures to date, but also ex-ante, to estimate the project policy impacts. This provides a useful benchmark to assess whether the policies are on track to deliver the anticipated level of savings. (D. Forster, et al.,2009)

It is important to recognize that the policies and measures that are covered by the European Climate Change Programme are also influenced by a range of other policy objectives, i.e. climate change mitigation is unlikely to be the only driver. Indeed, for certain policies, climate change mitigation is not the primary driver, together with other more important policy drivers.

A number of climate policies will also have an important influence upon other environmental objectives. Of particular note is the interrelationship between air quality and climate change objectives, where there is a large potential for synergistic effects. Consequently, policies are frequently appraised to reflect the impacts on these duel-objectives[20.]

On this basis, it is important to recognize that the design, implementation and operation of ECCP policies and measures are done so as to optimize a range of welfare benefits.

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[20] For example, the NEC-Directive Review has considered the cost-effectiveness of the abatement techniques including both air quality (SO2, NOx, PM) and greenhouse gas pollutants (CO_2 etc).

Therefore, the focus of this report on GHG abatement represents just a sub-set of the total impacts.

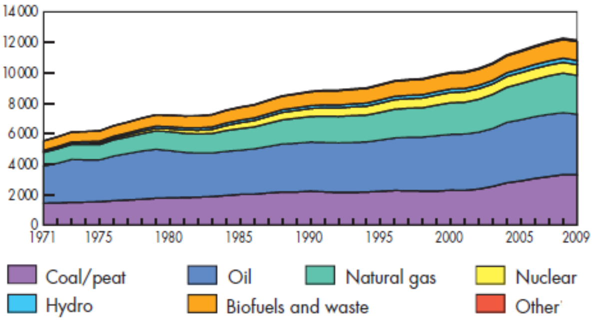
6. The composition and evolution of world demand

Currently, the annual demand for energy exceeds 12 200 Mtoe, this is divided by the sum of different types of primary energy sources used. The oil represents a third of the demand, the carbon 27% and the gas 21%. The remaining 18% is composed by almost 10% of renewable energy, 6% of nuclear and 2% of hydropower.

The following figure shows the composition of the energy demand and the consumptions in the last 35 years. The difference of 30% between demand and supply depends on losses during the transport and the refining process as well as possible changes in the stock of reserves.

The historical evolution of the demand of primary sources shows that in the last 40 years the energy production has essentially doubled (in 1973 it was 6 163 Mtep). The oil is gradually decreasing, it passed from 46% 40 years ago to 33% nowadays. It has been replaced by natural gas (+5%), nu2clear (+4%) and carbon (+2.5%). In 2009 the world consumption of energy has decreased for the first time in the last 30 years (-1.1%); this reduction has been the effect of financial and economical crises (GDP drop by 0.6% in 2009).[21]. The energy market in 2010 has started again to increase, and the energy consumption shows a growth rate of 5%.

Figure 1.2: Trend of world total primary energy supply from 1971 to 2009 (data in MTep)



Source: International Energy Agency

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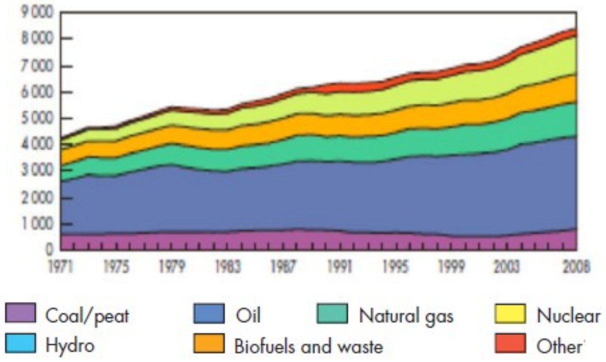
[21] Data Wordbank

Figure 1.3: Trend of world consumption of primary energy between 1971 and 2008 (data in MTep)



Source : International Energy Agency

7. Energy Performance of Buildings

The buildings sector represents 40% of the European Union's (EU) total energy consumption. Reducing energy consumption in this area is therefore a priority under the "20-20-20" objectives on energy efficiency. This Directive contributes to achieve this aim by proposing guiding principles for Member States regarding the energy performance of buildings.

7.1. Directive 2002/91/EC on Energy Performance of Buildings

This Directive aims to promote the energy performance of buildings and building units.

The objective of the Directive 2002/91/EC is to promote the energy performance of buildings within the European Community taking into account outdoor climatic and local conditions as well as indoor climate requirements and cost-effectiveness.

The objective of this Directive is to promote the improvement of the energy performance of buildings within the Community, taking into account outdoor climatic and local conditions, as well as indoor climate requirements and cost-effectiveness. This Directive lays down requirements, as regards:

(a) the general framework for a methodology of calculation for the integrated energy performance of buildings;

(b) the application of minimum requirements on the energy performance for new buildings;

(c) the application of minimum requirements on the energy performance for large existing buildings, that are subject to major renovation;

(d) energy certification for buildings;

(e) regular inspection of boilers and air-conditioning systems in buildings and, in addition, an assessment of the heating installation, in which boilers are more than 15 years old.

7.2. Key results Appliance Labelling Directive (92/75/EEC)[22]

The purpose of this Directive is to enable the harmonization of national measures on the publication, particularly by means of labelling and of product information, information on the consumption of energy and of other essential resources, as well as additional information concerning certain types of household appliances, thereby allowing consumers to choose more energy-efficient appliances. This Directive shall apply to the following types of household appliances, even where these are sold for non-household uses:

- refrigerators, freezers and their combinations,
- washing machines, driers and their combinations,
- dishwashers,
- ovens,
- water heaters and hot-water storage appliances,
- lighting sources,
- air-conditioning appliances.

The details about the French and Italian Directives are reported in the follow sections.

8. French environmental policy

France has a very ambitious environmental-policy agenda, aimed, chiefly, at cutting greenhouse gas (GHG) emissions, but also at dealing with local air and water pollution, waste management and conservation of biodiversity. The laws that followed the *Grenelle de l'environnement* concern policy measures in energy generation, manufacturing, transport, waste management, construction and agriculture to encourage a transition towards a low-carbon economy. The government is committed to an ambitious GHG reduction objective of 75% to be achieved by 2050. (E. Balázs, 2012)

The potential for further reduction in GHG emissions

GHG reduction targets should be aligned with marginal abatement costs and, thus, possibly with the absolute level of emissions, given a worldwide target. The government's plans to reduce GHG emissions by 2020 and 2050 are very ambitious, in that France has been so far a top performer in terms of the absolute level of GHG emissions. In 2007 and 2008, France emitted less GHGs than its G-7 peers in absolute terms, but also when measured on a per capita or per GDP unit basis; in the OECD area, only Sweden and Switzerland did better. The main reason for France's outstanding

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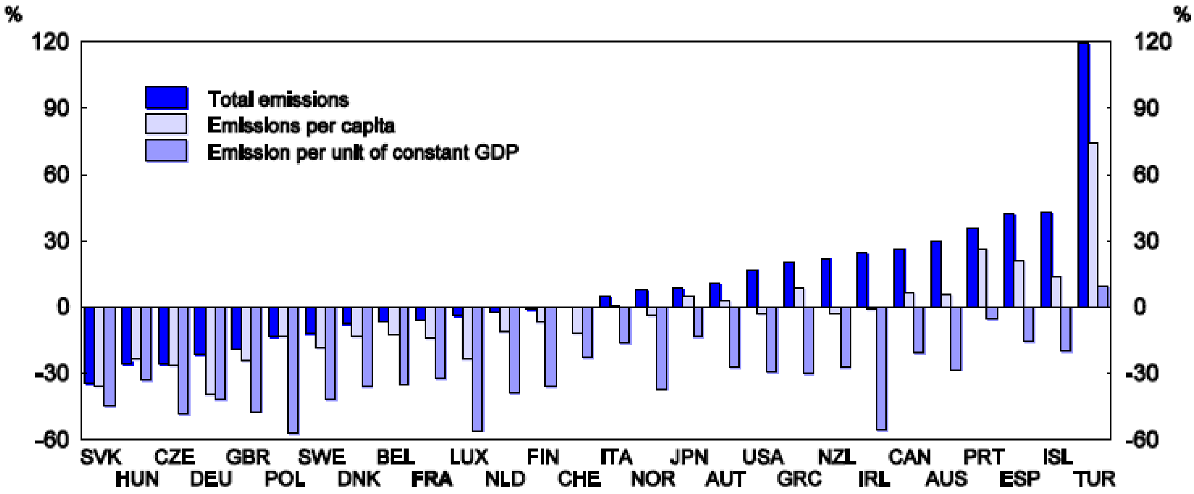
[22] Council Directive 92/75/EEC of 22 September 1992 on the indication by labelling and standard product information of the consumption of energy and other resources by household appliances

position is that a large proportion of electricity generation uses low-carbon nuclear and hydroelectric technologies.

Figure 1.4: Changes in % GHG emissions (excluding LULUFC), 1990-2008[23]



Source: OCED, National Accounts and Demography and Population Database, OECD calculations based on absolute emissions data draw from UNFCC and Eurostat.

Reducing GHG emissions further, will require increasing the carbon efficiency of output. Because some other OECD countries and large emerging economies, such as China, India and Russia, emit up to 13 times more greenhouse gases per unit of GDP than France[24], cutting GHG emissions in France is unlikely to be the most cost-efficient global solution (Prud'homme, 2009). But it can be justified on the grounds of equity: if all countries, rich and poor, were allowed to have similar per capita GHG emissions, after reducing global GHG emissions by 50% by 2050, France still would need to lower per capita emissions (Prévot, 2007). Yet, the quantity of the reduction would be smaller than the official objective.

A cross-country comparison of sectorial GHG emissions

Against this backdrop, cutting GHG emissions by 75% will be much more costly in France than in other major European countries. In 2007, per capita GHG emissions in public electricity and heat production were as low as 0.8 tone per person in France, while the corresponding statistic ranges from 2.0 tons in Italy to 4.2 tons in Germany. Consequently, most of the cuts in France will have to come from other sectors of the economy. A comparison of per capita emissions in other sectors reveals no major

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[23] LULUCF means: land use, land-use change and forestry change.

[24] The ratio of 13 is obtained by dividing global GHG emissions compared to nominal GDP in euro for China by the same ratio for France. The sources are the IEA for GHG emissions and the OECD for nominal GDP.

differences, with one exception: agriculture, although this reflects the relatively large size of the sector in France, rather than an unusually high intensity of emissions.

The «Grenelle de l'environnement»

Official estimates suggest that the existing and new measures would allow emissions in sectors outside the EU-ETS to be reduced by 18.3% between 2005 and 2020, compared to a -14% target for France within the EU.s, burden-sharing plan in these sectors (MEEDDM, 2008a). The government expects the new measures taken to impact almost exclusively on energy use in electricity generation, manufacturing, transport, tertiary sector and agriculture, with a cut of 29% in GHG emissions, compared to the scenario of no additional measures taken, whereas GHG emissions not related to energy use in industrial processes, agriculture and waste management would either remain unchanged, or fall only marginally (MEEDDM, 2008b). Another objective is to increase the share of renewable energy to 23% in total final energy consumption by 2020. In fact, the French government's climate change mitigation policy can be viewed as a transposition of the EUs triple 20 plan, according to which a 20% reduction in GHG emissions by 2020 compared to 2005 should be achieved, thanks to the cut of energy consumption by 20% and the increase in share of the renewable energy to 20% in total energy consumption

Smoothing peak demand

Given that roughly 90% of France's electricity production is virtually carbon free thanks to its stock of nuclear and hydroelectric power plants, a further decarbonization should target the remaining 10%, which mainly relates to semi-base and peak electricity production. Coal-fired power plants should be replaced by fast-reaction natural gas-fired plants, and peak demand should be smoothed to decrease the demand for high-carbon electricity produced by fossil fuel-fired plants. Nonetheless, the *Grenelle de l'environnement* aims at a considerable increase in the share of renewable energies in total electricity production. Against this background, a careful analysis should determine the least-cost options.

Electricity generation in France is characterized by an excess base-load capacity reflected in electricity exports, and an increased peak demand that can be covered only by electricity imports during some 60 hours per year (Rapport Poignant-Sido, 2010). Serving electricity demand during peak periods requires rapid-response capacities, as demand and supply need to be balanced continuously in the electricity grid. Quick-response generation capacity usually relies on high-carbon content technology, mostly oil in the case of France. As a result, smoothing peak demand can contribute to lower GHG emissions. Peak demand has daily, weekly and annual patterns, the latter being mostly associated with the heating season and cold waves, since a considerable number of French households uses direct electric heating or has switched recently from fossil fuel to alternative heating technologies, such as heat pumps, which are using electricity as an input. The seasonal pattern in electricity demand can be smoothed over two complementary ways: smoothing demand and lowering the carbon content of semi-base and peak supply.

On the supply side, electricity produced during periods of low demand relying on low-carbon technology, such as nuclear or renewable energies, should be stored, and then used when demand is high. Currently, the only technology available on an industrial scale is electricity, stored in the form of water behind dams. Yet, there are strong geographical and ecological constraints on a significant expansion of hydropower capacity in France. New technologies, including electricity storage with air compression, may change the status quo. In addition, the electricity sector's multi-year investment plan recognizes the scope to cut the carbon content of the semi-base-load by investing in gas-fired power plants to replace coal-fired plants, but nevertheless, this emphasizes the need to maintain oil-fired plants in order to meet peak demand (MEEDDAT, 2008a).

Encouraging other forms of renewable energy

The French government uses two main instruments to promote renewable energy. First, the tax system includes a tax credit for the purchase of equipment, and a reduced VAT rate of 5.5% is applied to equipment used for investment in small solar energy plants (<3kWe). Second, mandatory feed-in tariffs imposed on EDF or local distribution firms and set by ordinance above the market price of electricity for terms of up to 20 years have been introduced to ensure that electricity producers can at least break even on investment. In addition, feed-in tariffs are often used to support infant industries or innovative activities, although broader and less targeted support, including access to venture capital and an innovation policy, encouraging basic and applied research, would seem to be more effective. Feed-in tariffs were first introduced in 2001-02 for electricity generation technologies that make use of solar, wind, tidal wave, geothermal and hydro energy, biomass and biogas. They were revised upwards for solar, geothermal and hydro energy and biogas but were regressive for wind. There is a large dispersion in feed-in tariffs across renewable energies. But there is also a substantial variation for a given source of energy. Feed-in tariffs may depend on the installed electricity generation capacity, the specific technology used (offshore versus onshore wind, rooftop or ground-based solar panels), the geographic location (metropolitan France versus Corsica and overseas departments for solar and geothermal energy, geographical situation on a North/South gradient in metropolitan France), energy efficiency (biogas and biomass) and the season of the year (winter versus summer for hydroelectric power plants). Two important issues with regard to feed-in tariffs are: the implicit subsidies to producers, due to what is for a set period of time an above-market selling price; and the cost of an avoided ton of CO_2 equivalent GHG emission, due to the specific technology supported by feed-in tariffs.

The costs implied by the feed-in tariffs for abating one ton of CO_2 equivalent GHG emissions depend crucially on two parameters: the excess of the feed-in tariff over the market price and, very important, the carbon-intensity of the power generation technology that is displaced by the subsidized technology[25].

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[25] In a given multi-year phase of the EU-ETS, a decrease in one country's emissions will allow more emissions elsewhere. Nevertheless, decreases in emissions may be constraining in the longer term, if the overall emissions ceiling is adjusted for reduced emissions between two multi-year phases of the EU-ETS.

Previous OECD work (OECD, 2004) computed the abatement costs of measures promoting renewable sources of energy by assuming that the investment in electricity production, based on renewable energies, will replace natural gas-fired combined-cycle turbines, as the benchmark technology, that would be a natural choice for increasing capacity. We take a different view, and argue that two different benchmarks should be used. It should be stressed that the abatement costs calculated here are lower-bound estimates, given that investment subsidies are not taken into account.

The first benchmark is the most carbon-intensive technology, namely coal-fired power plants. This choice permits the comparison of the least-cost abatement options in each country[26]. The abatement costs are a linear function of the feed-in tariffs in excess of the market price of electricity (as carbon intensity for the displaced technology is held constant across countries): abating GHG emissions in the French electricity sector appears to be the most expensive if photovoltaic is the replacement technology. These abatement costs are, respectively, between the highest and lowest in the OECD. Abatement costs for other sources of renewable energy are closer to the OECD average.

The second and perhaps more appropriate benchmark is the country actual electricity mix if a significant rise in the share of renewable energies crowds out all existing technologies. For France, the 23% objective for renewable energy in the global energy mix coupled with a current share of 75-80% of nuclear energy in electricity production would mean that low-carbon renewable could replace an existing low-carbon technology, obviously at a very high cost[27]. The lower the carbon intensity of a country's electricity mix is, the higher the abatement cost associated with a given low-carbon technology would be.

The reducing GHG emissions is extremely expensive in France and Switzerland, while it is much cheaper in countries with a higher share of coal-fired power plants, such as Germany, Denmark and Poland.

8.1. The residential sector

The government hopes to achieve lower GHG emissions in the residential, commercial and government sectors by reducing the consumption of primary energy sources by 38% by 2020, and by generating a switch from fossil to renewable sources for heating purposes. For residential housing, which represents about three-quarters of the total heated space, the current annual average energy consumption of 240 kWh per square meter is expected to be reduced to 150 kWh[28] by two main channels.

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[26] The abatement cost is minimized if the most carbon-intensive technology is displaced

[27] A more general problem of solar and wind energy is that such energy depends on weather conditions, and therefore has to be backed up by more reliable energy sources, both for base and peak-load electricity generation. But technological progress in storing electricity other than pumped hydro would attenuate this problem.

[28] Source OECD calculation, Organisation for Economic Co-operation and Development, www.oecd.org

First, stringent norms will impose very low energy consumption of 50 kWh for new residential buildings from 2012 onwards, and “energy-plus”[29] buildings, designed to produce energy to cover their own energy demands, starting in 2020. The second is through an energy efficiency improvement of the existing buildings. The renovation of the current stock and the modernization of heating systems are supported by a tax credit for sustainable development (*crédit d’impôt développement durable*), an environmental zero interest loan (*éco-prêt à taux zero*), a low-interest credit assigned for eco-friendly social housing, and a reduced VAT of 5.5% for a variety of equipment. The conditions for access to the tax credit and the reduced VAT were tightened in 2010. Even though MEEDDAT (2008) presents abatement costs for the energy consumption of new buildings and thermal renovation of public and private buildings, it would be desirable to introduce a systematic analysis of specific measures in terms of abatement costs, both to determine the cost of public subsidies, and to improve the cost efficiency of the measures.

Since 2006, energy providers (electricity, gas, heating fuel and district heating, of which nearly 80% is supplied by EDF and GDF Suez) are required to secure energy savings. A similar system was put in place in 2002 in the United Kingdom and in 2005 in Italy. Energy providers have the obligation to reduce the energy sold with the help of increased energy efficiency of their final customers. If they miss the reduction target, they have to pay 2 cents for each kWh by which they fail to meet the target. Certified energy reductions are rewarded by the so-called white or energy-saving certificates, which can be used for a providers own target compliance, or can be sold to other providers that cannot meet their targets. As in any other cap-and-trade system, the incentives ensure that cuts are done where they are the cheapest. According to DGEC (2009), in 2009 92% of white certificates[30] were concerned with residential and commercial buildings, of which improvements to heating systems and thermal isolation represented the major chunk, and the price of exchanged certificates remained below 1 cent per kWh. Energy savings during the first phase (1 July 2006, 30 June 2009) amounted to 60 TWh (compared to a goal of 54 TWh), i.e. 15% of the annual energy consumption for the housing sector in France. The system is now entering into its second phase from 1 January 2011 to 31 December 2013 with a target of 345 TWh, i.e. more than six times the goal for the first period (MEEDDM, 2009).

The building sector

In the last years there has been a progress in the knowledge of building sector. This is due to the valorization of different aspects:

- buildings can use multiple energy sources, including renewable energies. These energies can be combined and change several times over the life of the building;
- works to improve the energy performance of buildings can be programmed over several years and this trend increases the value of the building;

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[29] The Passive House represents today's highest energy standard with the promise of slashing the heating energy consumption of buildings by 90%.The total energy demand for heating and cooling of the parts must be limited to 15 kWh/m2 of conditioned area.

[30] White certificates are a new policy instrument aimed at accelerating the diffusion of energy efficient technologies.

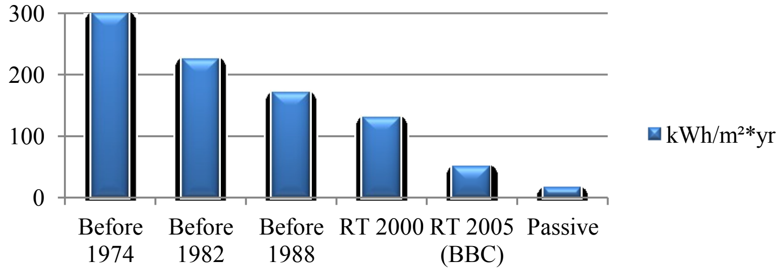
- the building occupants use behaviors that are relatively constant over the time. Their needs change over long cycles and can be reasonably anticipated.

In France the thermal regulation (RT) for buildings is highly regulated since 1975. This is part of a group of action against the energy saving. The main steps of this regulation are:

- RT 1974: the first regulation on the residential sector was implemented to limit the overall heat loss. It provides for 25% reduction in heating consumption.
- RT 1989: it provides for a global thermal performance for heating and hot water: a further reduction in consumption of 25%.
- RT 2000: there are prefixed targets on average consumption: less than 7% in residential and 25% in tertiary.
- RT 2005: it was imposed a level of performance required by the BBC[31], with a goal of improving the energy performance in new buildings by at least 15% compared to the RT 2000 (40 % in 2020), and limiting the use of cooling.
- RT April 2008 concerning residential sector: the energy consumptions lie between 80 and 195 kWh/m2/year, with a minimum performance on each element: ventilation, walls, ECS, glazing , cooling, lighting, heating, ENR.

The following Figure shows the evolution of consumption in kWh/m^2*yr of primary energy required by the different stages of thermal regulation.

Figure 1.5 : Trend of consumption in kW/m^2*yr of primary energy imposed by the different steps of thermal regulation.



Source : B. Duplessis, Centre Énergétique et Procédés-Mines ParisTech, 2011-2012

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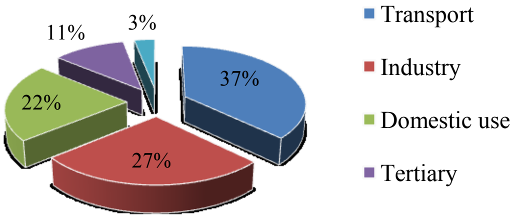
[31] A low-energy house (BBC-*Bâtiment de basse consommation énergétique*) is a building that respects the French law published in the Official Journal (*Journal Officielle de la Republique Française*), which specifies that for the new residential constructions, the objective of maximal consumption in primary energy is fixed to 50 kWh/m².year – to be modulated according to regions and altitude.

8.2. Energy situation in France

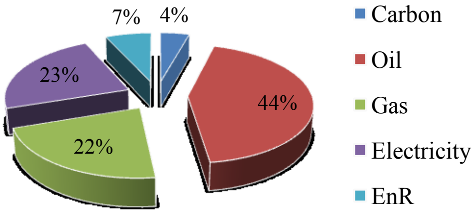
France consumed, based on estimates of SoeS[32], in 2007 the equivalent of 159 Mtoe of final energy. The French consumption per capita lies within the EU average (the equivalent of 4.3 tons of oil per year). The transport represents the highest consumption sector, followed by industry; the residential sector consumes about 22% of the total consumption.

Figure 1.6 : Distribution of consumption of final energy by sector in France, in 2007



Source : MEEDDM/SOeS, 2007

Figure 1.7 : Distribution of final energy consumption by energy in France, in 2007



Source: MEEDDM/SOeS, 2007

In 2007, residential and tertiary buildings consumed 33% of the final energy consumption in France. Two-thirds are consumed by residential sector, one third by tertiary, 60% of the energy consumed by residential-tertiary is devoted to heating, 25% for specific electricity (lighting, cooling ...) and 15% for other uses, mainly hot water and cooking.

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[32] «Observation Et Statistiques», Ministère De L'écologie, Du Développement Durable Et De L'énergie, Commissariat Général Au Développement Durable, http://www.statistiques.developpement-durable.gouv.fr/. SOeS produces data and information on the topics of housing and construction, transportation, energy and climate, environment and sustainable development.

After an average increase of 1.5% per year over the period 1990-2001, energy consumption in the residential-tertiary then capped: it returned in 2010 to 2001 level. However, there are structural factors that increased consumption, that is: increased park buildings, diffusion of new needs, such as microcomputers or cooling.

The stagnation of consumptions reflects an improvement of the energy performance in buildings, due to the renovation of energy efficiency within the existing houses, as well as the improvement of the thermal regulation in the new buildings

9. Italian environmental policy

The EU climate and energy package plan, to reduce GHG emissions by 2020, and approved by the European Union, is a national plan binding on member countries such as Italy. The Directive 2009/28/CE in Italy provides an electric production from renewable sources amounting to 17%.

The National Energy Strategy, that has been implemented after the introduction of the Directive 99/2009[33], can provide Italy with a long term integrated vision to energy sector. This strategy should allow to achieve the following objectives:

- Diversification of energy sources and geographical areas concerning the supply;
- Improvement of the competitiveness of the national energy system and development of its infrastructure;
- Promotion of renewable energy sources and energy efficiency;
- Increase investment in research and development in the energy sector as well as participation in international agreements on technological cooperation;
- Guarantees an adequate level of health protection for workers.

The building sector

Before April 30,1976, the date of the enactment of Law 373, no obligations existed. Nowadays the houses built without any attention to energy issues are approximately 64% of the buildings stock in Italy (17 million houses). The Law 373/76 was made up of three parts: the first one concerned the production of the heat and the annexes thermoregulatory systems, the second was the thermal insulation of buildings and the third the penalties for those not observing such laws.

The Law 10/91 was the first law, implemented into the National Energy Plan, about the design methods and the management of the buildings and systems. The Article 11 contains the rules for saving energy and for the use of renewable energy.

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[33] Law of July 23, 2009, n. 99 "Provisions for the development and internationalization of enterprises, as well as in the field of energy" published in the Official Gazette no. 176 of July 31, 2009.

The Directive 93/76/EEC is based on the limitation of CO_2 emissions by improving the efficiency (SAVE). The programs for the implementation of the law are relating to: energy certification of buildings; energy audits of businesses, cooling and hot water, thermal insulation of new buildings, regular inspection for boilers

The Directive 2002/91/CE defines the main strategies for the energy efficiency of buildings between the European States. It defines a methodology for calculating the energy performance of buildings; it imposes the respect of minimum energy efficiency standards for buildings of new construction and buildings undergoing restructuring; it develops a system of certification for energy performance in buildings.

The action plan for the energy efficiency (20-20-20) provides for Italy the achievement in 2020 of a reduction of 13% of CO_2 and of a production of 17% from renewable energy.

The Directive 192/05 has been created to reduce the energy consumptions. It is applied to existing works of renovation of buildings; exercise, control, maintenance and inspection of heating systems, energy certification of buildings.

The DM 26-9-2009 gives the guidelines for the national energy performance certification.

Finally has been emanated the Directive 31/2010/CE – EPBD Recast (Energy Performance of Buildings Directive). The main new of the Directive is the label for the new constructions: by December 2020 the constructions built have a high performance with a very low energy consummation[34].

9.1. Energy situation in Italy

In 2008 the energy supply of primary energy (TPES) in Italy was 147, 5 million (Mtep). Between 1990 and 2008, the TPES increased of 19%. Italy imports the biggest part of oil and gas, but there is also an interesting part of energy deriving from renewable sources, that is produced within the country itself. In the last year, the dependence on import is increasing and is particularly high for electricity is concerned (15.4% approximately)[35]. This structure carries two main risks: the stability of supply, and its price.

The main characteristics regarding the energetic situation in Italy are:

- import, which represents 88% of the total primary energy consumption
- 12% of local energy production derives from the exploitation of natural gas and oil, as well as from the generation of electricity by renewable sources
- most of the importation of oil is used in the transport sector.

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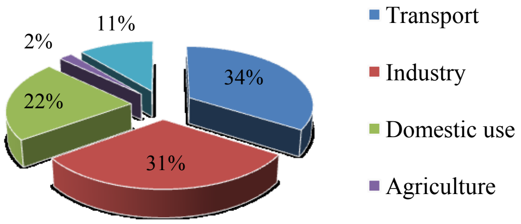
[34] "Nearly zero energy buildings"; the energy requirements should be covered, to a very significant extent, by energy from renewable sources, including that energy, still from renewable sources, produced on-site or nearby.

[35] Electricity information, IEA/ OECD Paris , 2009.

The total final energy consumption in Italy in 2007 amounted to 142 Mtep[36]. Transport represents the most consumption sector, followed by the industry; the residential sector consumes about 2% of the total consumption.

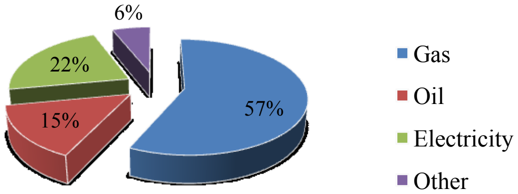
The following Figures show the distribution of final energy consumption by sectors, and the details about the residential sector in Italy.

Figure 1.8 : Distribution of consumption for final energy, by sector, in Italy in 2007



Source ENEA[37], Rapport « *Energia e Ambiente* », 2007-2008.

Figure 1.9 : Distribution of consummations by energy in residential sector, in Italy in 2008



Source: ENEA 2008

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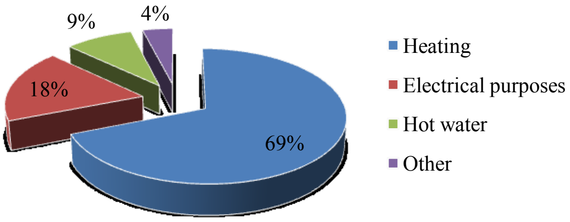
[36] Source Eurostat, 2007. http://epp.eurostat.ec.europa.eu/

[37] ENEA stays fo**r:** Italian National Agency for New Technologies, Energy and Sustainable Economic Development. Pursuant to art. 37 of Law no. 99 of July 23rd, 2009, the Agency's activities are targeted to research, innovation technology and advanced services in the fields of energy.

Figure 1.10 : Distribution of consummations by uses in residential sector in Italy in 2008



Source: ENEA 2008

2.
LITERATURE REVIEW

The environmental and energy issues are more and more influenced by political decisions and orientations. For that, it's important the evaluation of climate policies by constructing models. There are in literature lots of methodologies for the evaluation ex-ante and ex-post for climate policies.

An important sector, which is highly influenced by these issues and politics, is the building sector. This section introduces a scientific bibliography on buildings modelling methods.

As mentioned above, most of Member State had no formal or unique methodology. This means that the methodological assumptions and data sources vary frequently among different studies.

There are currently no standardized methodologies or models for the evaluations of buildings performance. This is influenced by different factors: scale of details (national, regional, building…), time horizon (2012, 2020, 2050..) and different possible livers (political orientation, their behavior…).

A number of methodologies can be used, and have been used. These methodologies can be broadly categorized as:

- Top-down methods, which generally use macro-level statistical data for evaluating the impact of measures.
- Bottom-up methods, which allow more detailed modelling for the impact of policies and measures, by determining what kind of technology or behavior is influenced by such measures, and in what way.
- Integrated methods, which are combing elements from both top-down and bottom-up methods.

1. Buildings modeling methods

Efficient and rational implementation of building efficiency strategies and policies requires the application of comprehensive building stock models (M. Kavgic, et al., 2010) which have the ability to:

a) estimate the baseline energy demand of the existing building stock,
b) explore the technical and economic effects of different indicators (e.g. CO_2 emission reduction) strategies over time, including the impact of new technologies,
c) identify the effect of emission reduction strategies on indoor environmental quality.

In the environment policy, with a rapid and substantial improvement in energy performance across all levels of governance, (which is nevertheless similar in its multifaceted character to what already exists, or is likely to occur in many nations), it is essential that robust and accurate models be available, so as to inform and evaluate specific policy measures. Building stock models for energy consumption represent a key tool for assisting efficiently and rationally the implementation of policy. Among other criteria, these models should ideally have the ability to:

a) estimate the ‘baseline’ energy consumption for the residential housing sector, disaggregated by building or social categories and energy end-use, explore the technical and economic effects of different energy efficiency strategies over time, including the impact of new technologies, such as renewable,
b) never be confined to issues directly related to energy, but instead being able to identify the effect of emission reduction strategies on indoor environmental quality.

In recent years, a plethora of disaggregated national level energy demand models has been developed, varying considerably in terms of their data input requirement and disaggregation levels, as well as socio-technical assumptions, being made about building operation, and hence in the type of results and scenarios they can reliably evaluate. Both policy developers and building scientists would benefit from a better understanding of the appropriate application and limitations of these models. Policymakers would greatly gain if they were able to establish which building parameters are the main key for national carbon reduction strategies for dwellings, and to highlight policy challenges for climate and building stock.

The top-down and bottom-up approaches are the two fundamental classes of modeling methods used to predict and analyze various aspects of the overall building stock energy use performance and associated CO_2 emissions. (C. Bohringer, et al., 2007)

The following Table displays schematically the main characteristics of the bottom-up and top-down models. However, it is also the case that some of the more sophisticated models can combine components, where each of these approaches has been used.

Table 2.1: Benefits and limitations of bottom-up and top-down modeling approaches

	Characteristics Top-Down	Bottom-up statistical	Bottom-up building physics
Benefits	• Focus on the interaction between the energy sector and the economy at large energy and emission policies and scenarios • Capable of modeling the relationships between different economic • Avoid detailed technology descriptions • Able to model the impact of different social cost-benefit • Use aggregates economic data	• Include macroeconomic and socioeconomic effects • Able to determinate a typical end-use energy consumption • Easier to develop and use • Do not require detailed data (only billing data and simple survey information)	• Describe current and prospective technologies in detail • Use physically measurable data • Enable policy to be more effectively targeted at consumption • Assess and quantify the impact of different combination of technologies on delivered energy • Estimate the least-cost combination of technological measures to meet given demand
Limitations	• Depend on past energy economy interaction to project future trends • Lack the level of technological detail • Less suitable for examining • Typically assume efficient markets, and no efficiency gaps	• Do not provide much data and flexibility • Have limited capacity to assess the impact of energy conservation measures • Rely on historical consumption data • Require large sample • Multy collinearity	• Poorly describe market interactions • Neglect the relationship between energy use and macroeconomic activity • Require a large amount of technical data • Do not determinate human behavior within the model but by external assumptions

Source : M. Kavgic, et al., 2010

1.1. Top-down approach

The top-down modeling approach works at an aggregated level, typically aimed at fitting a historical time series of national energy consumption or CO_2 emissions data. Such models tend to be used to investigate the inter-relationships between the energy sector and the economy at large, and could be broadly categorized as econometric and technological top-down models. The econometric top-down models are primarily based on energy use in relationship to variables such as income, fuel prices, and gross domestic product to express the connection between the energy sector and economic output. They can also include general climatic conditions, such as population-weighted temperature, for a nation. As such, the econometric top-down models often lack details on current and future technological options as they rather place the emphasis on the macroeconomic trends and relationships observed in the past, rather than on the individual physical factors in buildings that can influence energy demand (MIT, 1997). More important, the reliance on past energy–economy interactions might also not be appropriate when dealing with climate change issues where environmental, social, and economic conditions might be entirely different to those previously experienced. They have no inherent capability to model discontinuous changes in technology. The technological top-down models include a range of other factors that influence energy use (e.g. saturation effects, technological progress, and structural change), however, they are not described explicitly within the models (D. Johnston, 2003). As an example of a simple top-down model, the annual delivered energy price and temperature (ADEPT) was recently developed for annual household energy consumption in the UK since 1970 (A.J. Summerfield, et al., 2010).

This is a regression model based on an average heating season temperature and on an inflation adjusted energy price. The aim of the ADEPT model is just to allow yearly consumption data to be compared with what might be expected after allowing for the prevailing temperature and price settings. It provides policymakers and public a straightforward way of determining if changes are outside that expected from these basic drivers (and as might be anticipated to occur from major changes in the energy performance of the stock). So, while the model acts to prevent any reductions in national energy consumption, which are associated with warmer conditions or price changes from being automatically ascribed to fundamental improvements in the sector, it is not intended to explain consumption in more detail, such as quantifying the role of other factors and the effectiveness of specific policy measures.

1.2. Bottom-up approach

Bottom-up methods are built up from data on a hierarchy of disaggregated components, which are then combined according to some estimate for their individual impact on energy usage. This implies that they may be useful for estimating how various individual energy efficiency measures impact on CO_2 emission reduction, such as by replacing one type of heating systems with another. Often these models are seen as a way to identify the most cost effective options to achieve given carbon reduction targets based on the best available technologies and processes (N. Rivers, M. Jaccard, 2005). The bottom-up models work on a disaggregated level, and thus need extensive databases of empirical data to support the description of each component (L. Shorrock, at al., 2005). Contingent upon the type of data input and structure, statistical and building physics based methods represent two distinct approaches applied in the bottom up models to determine the energy consumption of specified end-uses (L.G. Swan, V.I. Ugursal, 2009a).

1.2.1. Approach based on building physics

Building physics based modelling techniques generally include the consideration of a sample of houses representative of the national housing stock and utilization of a building energy calculation method to estimate the delivered energy consumption (L. Shorrock, J. Dunster, 1997). Therefore, they require data input composed of quantitative data on physically measurable variables, such as the efficiency of space heating systems and their characteristics, information on the areas of the different dwelling elements (walls, roof, floor, windows, doors) along with their thermal characteristics (U-values), internal temperatures and heating patterns, ventilation rates, energy consumption of appliances, number of occupants, external temperatures, etc. (A.J. Summerfield, et al., 2010).

The combination of building physics and empirical data from housing surveys and other data sets, as well as assumptions about buildings operation, give modelers the means to estimate energy consumption in dwellings for the past, present, and future. By developing different scenarios, the bottom-up models appear to have the potential to be used to assess the impact of specific carbon reduction measures on the overall energy demand (D. Wilson, J. Swisher, 1993), which can be used as part of an evidence based approach to medium to long term energy supply strategy. In Europe, bottom-up building physics stock models are seen as useful tools to provide for policymakers with estimates for the effectiveness of policies, and can help to identify technological measures that can help end-use efficiencies.

In the UK, for example, the most widely used physically based model for the calculation of domestic energy demand is BREDEM[38]. (B.R. Anderson, et al., 1985 ; C.M. Dickson, et al., 1996). It consists of a series of heat balance equations and empirical relationships to produce an estimate of the annual (B.R. Anderson, et al., 2001) or monthly energy consumption of an individual dwelling. Importantly, an annual modified version of BREDEM (BREDEM-9) forms the basis of the UK Government's Standard Assessment Procedure (SAP) which is used for the energy rating of dwellings. One of the main advantages of the BREDEM algorithms for model developers is their overall modular structure, so that they can be easily modified to suit particular needs. For instance, BREDEM determines the electricity use for lights and appliances using simple relationships based on floor area and occupant numbers, which can easily be replaced by a more sophisticated approach, if needed.

One of the main weaknesses of building physics models lies in the many assumptions made regarding the role of behavioral factors on energy consumption, for instance in estimating the impact of changing demographic factors related to an aging population and hours of occupancy and heating system use. These issues, among others, are discussed in more detail in subsequent sections.

1.2.2. Statistical models

A detailed review of the statistical techniques used for modeling energy consumption of the residential sector can be found elsewhere (L.G. Swan, V.I. Ugursal, 2009b). Even though, there is a wide array of statistical modeling techniques available, most of the bottom-up statistical models are based on regression techniques (A.S. Fung, 2003; M.F. Fels, 1986) Even though, all of these methods can be used to model residential energy consumption, they do not provide much detail and flexibility and, therefore, have restricted capacity to evaluate the impact of a wide range of energy conservation scenarios (A.S. Fung, 2003). For example, the Princeton scorekeeping method (PRISM) (M.F. Fels, 1986) has been used broadly in the US by many governments, utilities and research organizations to analyze conservation and refurbishment measures in buildings. PRISM is a two-variable (a constant and a slope) linear regression model that uses a year of monthly billing data from a dwelling to create a weather-adjusted Normalized Annual Consumption (NAC) index of consumption. It has been applied to characterize energy conservation measures in a number of US regions, such as New Jersey and St. Louis, by developing a simple model for monitoring natural gas consumption in large aggregates of houses based on the individual-house scorekeeping approach.

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[38] BREDEM (The Building Research Establishment's Domestic Energy Model) is the name given to a family of simple but reliable energy calculation procedures for dwellings. BREDEM can be used for: estimating energy requirements in different dwelling types, estimating possible running costs of a property, ensuring the most appropriate measures be selected when upgrading existing dwellings, estimating the savings arising from energy efficiency measures, calculating an energy rating for a dwelling, estimating internal temperature conditions for a given energy input. It was first developed in the early 1980s and, as a result of continuous testing and development, it has become very widely used.

1.2.3. Hybrid models

While it is the case that building physics based models also rely on statistics for much of their empirical data, for instance average hot water demand per person, some of the more sophisticated models combine, in a more fundamental way, components where both building physics and statistical approaches have been applied. The Canadian Hybrid Residential End-use Energy and Emission Model (CHREM) (L.G. Swan, et al., 2009) is a typical example of a hybrid model. CHREM, which relies on the 17,000 detailed house records, implements the neural networks technique (L.G. Swan, et al., 2009; A. Mohmed, et al., 2008). This model consists of two energy modeling components, statistical and physics based component, that are used to estimate the energy consumption of the major end-use groups:

a) domestic appliances and lighting,
b) domestic hot water,
c) space heating and cooling.

The CHREM employs a calibrated neural network model as the statistical half of the model for use in estimating the annual energy consumption for appliances, lighting and domestic hot water loads as they are predominately influenced by occupant behavior (M. Aydinalp, et al., 2002; M. Aydinalp, et al., 2004). Estimation of space heating and cooling loads is accomplished using the high-resolution building performance simulation package ESP-r as there is no relevant historic data for statistical analysis of new buildings.

2. Scenario methods

No amount of sophistication is going to allay the fact that all your knowledge is about the past and all your decisions are about the future (Wilson 1975)

The scenario methodology is a complementary approach for the evaluation of climate policies. They are used in all fields of science and society where strategic planning depends on assumptions concerning the future. The Intergovernmental Panel on Climate Change[39] affirms: “Scenarios are coherent, internally consistent and plausible descriptions of a possible future state of the world. They are not a forecast, and this is an important attribute; rather, each scenario is one alternative image of how the future can unfold.”

The development of scenario methods are a strategic management and organizational learning tool, and were pioneered by business community in the 1960s. Strategic management studies of scenarios have described how the process of developing well-researched and plausible stories about the future can facilitate organizational learning, and generate critical insights into strategic decision-making. In energy research, scenarios

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[39] The Intergovernmental Panel on Climate Change (IPCC) is the leading international body for the assessment of climate change. It was established by the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO) in 1988 to provide the world with a clear scientific view on the current state of knowledge in climate change and its potential environmental and socio-economic impacts.

are most commonly used to characterize an envelope of expected future conditions or quantify savings potentials from policy, technology, or behavioral changes. Scenarios have gained prominence within the fields of climate change and energy efficiency.

The objective of developing scenario storylines is to create bounded contextual frames for exploring the future energy system from different perspectives. Energy scenarios examine a range of possible outcomes that are grounded within system dynamics of the energy system. Combining stories and models, scenarios qualitatively explore diverse contexts and quantitatively evaluate potential outcomes (R. Ghanadan and J.G. Koomey, 2005).

Scenarios are distinct from forecasts, in that, they explore a range of possible outcomes resulting from uncertainty; in contrast, forecasts aim to identify the most likely pathway and estimate uncertainties. As a result, forecasting models are most effective under conditions when information availability is extensive and understanding of governing dynamics is high. However, when systems are less well defined and interrelationships between factors are less stable and predictable, energy forecasts have shown themselves to be poorly equipped to characterize processes of change. Scenarios do not try to account for every possible outcome, rather they focus on developing a set of insightful lenses for exploring processes of change.

Table 2.2: Contrasting Energy forecast and Energy scenarios

	Forecast-What is likely?	Scenarios-What could be?
Approach	Rational focus on analysis and outcomes	Focus on process, strategy, and learning
Objective	To develop most likely pathway and characterize uncertainty	To develop a number of insightful pathways that explore uncertainties
Methods	Analytical models and driver variables	Qualitative stories evaluated by models
Treatment of uncertainty	Probabilistic methods, statistics, and transparency of assumptions	Exploration of critical uncertainties, and separation of predetermined and uncertain elements in crafting stories
Important actors	Reliance on experts, state and national planning agency	Group facilitators, strategists, problem-solvers

Source: R. Ghanadan and JG. Koomey, 2005

A study manned by R. Ghanadan and JG. Koomey, is an example of application of scenario methodologies. They developed and analyzed four energy scenarios for California, that are both exploratory and quantitative. They developed their study to understand how the state would move forward into the next 30 years, what priorities California's energy system would shape and what better decisions today could be learned from this (R. Ghanadan and J.G. Koomey, 2005). They would not predict what the future would be or even what it should be like. Rather they opened the doorway to possibilities. The methods, tools, and examples presented here are a starting framework for beginning this discussion, and an opportunity for creative engagement with the future.

Their study started with the exploration of a range of possible energy pathways for California, as well as the description of the different methodologies for developing the BAU and the three alternative scenarios around critical uncertainties in California's energy system. In the following section, the implications of the scenarios were examined, using energy modeling techniques to quantitatively evaluate some indicators (e.g. future energy consumption, composition of electricity generation, energy diversity, and greenhouse gas emissions), associated with each scenario through 2035. Finally, they presented a set of critical issues and policy implications illuminated by the analysis.

3. Example of Bottom-up, domestic energy

In this section, it is set an agenda for rethinking bottom-up UK domestic energy and carbon models (S. Natarajan, et al., 2011), as well as an examination of existing approaches to model domestic energy consumption and carbon emissions (DECCE). Moreover, there is a French application of a Bottom-up model with simulation in a long term.

Meeting target requires strategic planning, efficient resource management and technological development. An important tool to assess the viability of options is long term demand side scenarios, that balance future climate projections, demographic change and user behavior.

For example, Natarajan and Levermore recently demonstrated the technical challenges and opportunities that exist in meeting a 60% emission reduction target by 2050 (S. Natarajan, G.J. Levermore, 2007a). This work showed that the potential to decrease emissions to such levels exists, under at least three different scenarios, but each one requires a major departure from current policy and practice, if the required levels of reduction are to be achieved. For instance, the Tyndall Centre founded that 40% in the house approach requires a combination of rapid replacement (e.g. demolition of inefficient stock to be replaced by more efficient buildings) as well as a refurbishment of the existing dwellings and a good spread of domestic low and zero carbon technologies (K. Lane, et al., 2005). The BRE's Step Change 2 scenario relies heavily on prescribing a shift towards heat pumps and biofuel boilers to replace all current and future heating systems (L. Shorrock , et al., 2005). A third scenario suggested by Natarajan and Levermore found that failing the above two strategies, only a heavy uptake of low and zero carbon technologies (particularly solar PV for electricity consumption and export) could deliver the necessary cuts (S. Natarajan, G.J. Levermore, 2007b). Clearly, achieving an 80% reduction is likely to pose even greater difficulties.

3.1. Three bottom-up UK models analyzed

The focus will be on three current bottom-up UK models, each of which was used to produce one of the three scenarios above described. The BRE work uses the BREHOMES model (L. Shorrock, J. Dunster, 1997); the 40% House work uses the UK Domestic Carbon Model (UKDCM) and Natarajan's work uses the Domestic Energy and Carbon (DECarb) model (S. Natarajan, G.J. Levermore, 2007b). A common and fundamental feature of all three models is that although they were produced for different studies, they share the same energy model to calculate energy use and carbon emissions: the BRE's BREDEM model (B.R. Anderson, et al., 2002). This model has a well-established track record for producing accurate predictions of dwelling energy consumption in the UK. It uses building physics based algorithms, coupled with empirical data to arrive at energy consumption disaggregated by four end-use types (space heating, hot water consumption, cooking and lights and appliances). As BREDEM is modular, some elements can be replaced with more detailed sub-models. To date, this has mainly been done to replace the lights and appliances sub-model with the comparatively recent DECADE data (ECI, 2007).With more work being undertaken to validate other aspects of the domestic energy mix, such as the BRE's analysis of domestic hot water consumption from the 1998 EFUS survey (Building Research Establishment, 1998), other parts of the model could also be replaced. All three models have been successful in answering important questions on the feasibility of achieving long term carbon emission reductions. BREHOMES is frequently used to inform and justify government policy, UKDCM was used to produce the 40% House scenario – an important set of policy options to achieve 60% reductions – and DECarb was used to validate these approaches independently. However, there are some common limitations to the capabilities of these models.

3.1.1. The methodology

Although each model operates at a different level of disaggregation, they all adopt a common approach by defining an average performance for a number of dwelling categories that are then scaled up to build a UK-wide picture of domestic carbon emissions. Natarajan has previously demonstrated that less disaggregated models will produce results with lower confidence, while higher levels of disaggregation produce more accurate results as the averaging process can skew the individual energy and carbon profiles of dwelling categories unpredictably. For example, in the case of a scenario developed using a model with only two 'notional' dwellings (D. Johnston, et al., 2005), it was shown that the expected carbon savings predicted by the author were significantly overestimated (S. Natarajan, G.J. Levermore, 2007b). Although DECarb, UKDCM and, to a lesser extent BREHOMES, went some way towards lowering such reliance on average performance by producing heterogenous stock, they do not solve this problem.

A second aspect of this approach is deciding the granularity of the model. Clearly, a model with only one or two dwelling categories, is too coarse – but with how many categories is too fine? Evidently, this will depend on the granularity of the available data to feed these models. DECarb's base dataset and structure is directly informed by the granularity of house condition survey data: 8064 possible categories for each of six historic age-bands defined from seven metrics (6 wall construction types, 7 dwelling archetypes, 6 heating systems, 4 climatic regions and binary values for wall, window and roof insulation). Linear transformations are applied to these categories to produce future age-bands with 8064 categories each on a decadal basis. Where further categories need to be defined (for uptake of newer technologies, such as photovoltaic panels or solar hot water heating), they are disaggregated from this basic definition using a weighted average approach. BREHOMES uses 1000 categories for its base dataset, but only one composite dwelling for predicting future emissions, and UKDCM produces around 20,000 categories by 2050. Clearly, it is necessary to validate and harmonize these approaches to obtain a unified and consistent method that delivers the best mix of detail and robustness of output.

3.1.2. Conclusions

The existing modeling approaches will need to be reconsidered in order to meet future modeling challenges. Clearly, some of these issues can be solved by modifying current approaches. For example, the problem of probabilistic modeling can be attacked by adopting well established methods such as Monte Carlo simulations. New datasets can be incorporated by making piecemeal changes to existing code. Human–building interaction can be accounted for through implicit assumptions or through scenario specification. An example of this would be the current practice to account for changing thermal comfort expectations by specifying assumed demand temperatures. Conversely, other issues – such as the use of average dwellings, or the impact of the neighborhood – are not tractable through traditional (equation based modeling) methods. In fact, the use of average dwelling categories would have to be an inherent feature of any resource effective equational model.

3.2. A bottom-up France model analyzed

An important energetic study developed in France at regional scale is briefly explained in this section (Sogreah, 2011). The «*Etude Energétique de la Région Languedoc-Roussillon*[40], *Secteur Residentiel*» is a regional application of the evaluation of consummations and needs for the residential sector based on a bottom-up approach.

The study is divided into two part. The first, is the analysis of the existence situation of the regional sector based on calculus manned by the model CLE-BAT *Résidentiel*[41]. The results are subsequently compared with the measured data. The second part, is composed by the development of three scenarios in which the evolution of the sector in 2020 and 2050 is analyzed. The three scenarios developed are: a baseline scenario, a scenario "*Granelle*[42]" and a scenario ambitious. This study aims to underline the most issues of the orientations and the regional levers (e.g. the ambition of the new buildings, the retrofitting housing, renewal of heating and energy substitutions).

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[40] Languedoc-Roussillon is one of the 27 regions of France. It comprises five departments, and borders the other French regions of Provence-Alpes-Côte d'Azur, Rhône-Alpes, Auvergne, Midi-Pyrénées on the one side, and Spain, Andorra and the Mediterranean Sea on the other side.

[41] Model developed by Sogreah and La Calade

[42] Scenario "*Granelle*" aims to a consumption and emission reduction based on the regulation of "*Granelle de l'environnement*"

3.

ALSACE

Alsace is a pilot region for renewable energies and low consumption buildings. It has begun a politic of sustainability and development, durable for the whole region, based on actions on its resources as well as on the activities on different collectivities and industries. This policy is conducted with the collaboration of the ADEME[43] and "Energievie".

The EDF's group is linked with the historical economical Alsatian development by the development of its activities of production, transport and distribution of electricity, energy efficiency and energy commercialization. The EDF group has given his contribution for the regional sustainable development, and it has started the Energy Alsace program with the collaboration of the local collectivities.

Within the contest of Government and regional Project, the struggle against Climate Change in Alsace is based on two main axes: the control of energy consumption, and the development of renewable energy.

The following section will explain the main axes of the regional schema of climate, air and energy, elaborated by the DREAL[44] and the "*Conseil Régional d'Alsace*[45]". This document has been created as a strategy for all the local actors in order to reduce the GHG emission and the energy consumption[46].

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[43] ADEME is a French Environment and Energy Management Agency , it is a public agency under the joint authority of the Ministry for Ecology, Sustainable Development and Energy and the Ministry for Higher Education and Research. Its main m**issions are** encouraging, supervising, coordinating, facilitating and undertaking operations with the aim of protecting the environment and managing energy.

[44] Direction Régional de l'Environnement de l'Aménagement et du Logement Alsace

[45] Schéma régional : Climat Air Énergie Alsace, juin 2012, Direction Régional de l'Environnement de l'Aménagement et du Logement Alsace (DREAL), Service Énergie Climat Logement Aménagement, www.alsace.developpement-durable.gouv.fr; Conseil Régional d'Alsace, Direction de l'Environnement et de l'Aménagement, www.energivie.info

[46] This document approaches four main topics: the adaptation to climate change, the mastery of energy, the renewable energy and the quality of air.

1. The regional scheme for the Climate, Air and Energy

The increase of the international and national targets with different regional characteristics have oriented Alsace to special target and objectives:

- a Scenario “Factor 4 Proactive”, characterized by a reduction in GHG emissions of 75% between 2003 and 2050;
- 20% reduction in final energy consumption between 2003 and 2020, and a decrease of about 50% in 2050;
- prevention and reduction of air pollution through an overall reduction in emission of particulate and nitrogen oxides in the territory, focusing especially on sensitive areas;
- coordination of strategies to reduce atmospheric emissions through climate and energy strategies;
- increase production of renewable energy by 20% by 2020 through diversification of production chains;
- improve knowledge on the effects of climate change at territorial scale, to a better report of vulnerability and issues;
- integration of the adaptation to climate change within the regional policies to ensure the consistency of the measures implemented.

These orientations are actualized by five axes[47], identified in accord with the local politic programs and the energy agencies to the horizon 2020-2050. These axes are:

1. reduction of GHG emissions and the control on energy requirements;
2. adaptation of the territory and of the socio-economic activities according to the climate changes;
3. prevention and reduction of atmospheric pollution;
4. development of renewable energies;
5. increase of the territorial synergies between climate, air and energy.

It’s important to underline that the realization of the regional objectives is correlated with regional and European politics. The different impacts about all the politic orientations have been simulated so as to obtain a scientific formalization to the Alsatian ambitions. These projections are based on the AERE’s studies in 2008[48], together with the demographic prospection evaluated by INSEE[49].

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[47] Arrete N° 2012/52 Du 29 Juin 2012, Portant Schema Regional Du Climat, De L’air Et De L’energie, Le Préfet De La Région Alsace

[48] AERE’s studies in 2008

[49] France's National Institute of Statistics and Economic Studies (*Institut National de la Statistique et des Études Économiques*: INSEE) is a Directorate General of the Ministry of the Economy, Finance, and Industry. It is therefore a government agency whose personnel are government employees, although not all of

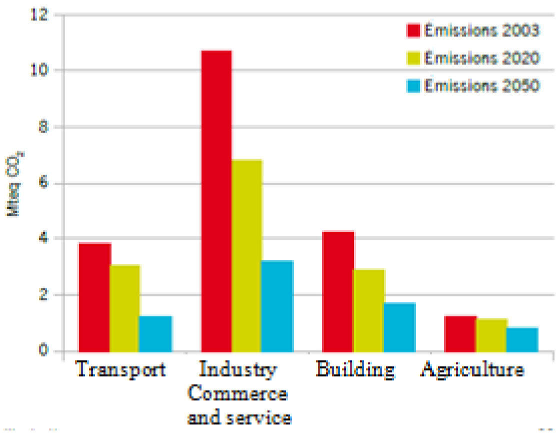
These studies show the necessity to apply certain actions. The main actions are about energy distribution, development and mobilization of energy renewable and change of habitants behaviors. The details of each axe are analyzed in order to present the actual context, the objectives and the future orientations.

1.1. The reduction of GHG emissions, and the control on the energy requirements

The reduction of GHG emission is often connected with the energy consumptions.

The national objective of "Factor 4" allows a reduction of 75% between 1990 and 2050. The scenario "Factor 4 Proactive" has been analyzed by Alsace, with the first step of 20% reduction from here to 2020. The future evolution of GHG emissions has been estimated, as illustrated in the Figure below.

Figure 3.1: Evolution of GHG emissions in Alsace from 2003 to 2050.



Source: « *Direction Régional de l'Environnement de l'Aménagement et du Logement Alsace* (DREAL) »

Concerning the energy reduction, the main target is the decrease of 20% of consummation on final energy between 2003 and 2020 and a 50% in the horizon 2050.

Based on these targets, the main orientations elaborated are:

- the energy renovation on the existence residential sector, based on the low consumption;
- the research of an ambitious energy performance on the new residential sector;
- performance development and renovation on the tertiary sector, based on low consumption;

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them are belonging to the civil service. INSEE operates under government accounting rules: it receives its funding from the State's general budget. http://www.insee.fr/

- control of the GHG emissions and improvement of energy efficacy;
- limitation of the wastes on energy transport;
- control of the GHG emissions and improvement of energy efficiency in regional agriculture.

1.2. The adaptation to climate changes

The analyses on climate evolutions have permitted to identify the Alsatian vulnerabilities. The main factors involved are:

- The exposition of the population to the extreme phenomena,
- The variation of availability of local resources,
- The variation of agriculture and forest activities.

The main regional aim is to anticipate the effects of climate changes on human activities and people's health.
In accord with the Regional targets, the main object for the quality of air, is to avoid the overcoming of target. The missed respect of the limit has its effect on people's health, and this is a problem, meticulously studied, within the "Regional plan of Health and Environment[50]".

1.3. The development of renewable energy

For the development of renewable energy each sector has fixed some quantitative and qualitative targets for 2020-2050, and has suggested some outlines of actions to be achieved.

The main outlines of actions are:

- Modernization of hydroelectric production,
- Optimization of biomass sector for energy uses,
- Valorization of waste of biomass,
- Acceleration on solar thermal energy heat production,
- Development of electricity production from solar photovoltaic energy,
- An harmonious planning for the wind energy development, based on the different territorial stakes.

1.4. The increase of the territorial synergies between climate, air and energy[51]

This part approaches three main themes: the schema dynamic and evolution, the public awareness of actors and the territorial declension. Indicators, based on different efforts and actions lied within the measures adopted, are the initial point for the evaluations.

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[50] Plan Régional Santé Environnement (PRSE)

[51] SRCEA, *Schema regional climat air énergie*, created by the Granelle in 2007, Article 68

The evolutions of behaviors on the energy consummations within the building sector is an important lever for the improvement of Alsatian performances for the fight against the GHG emissions.

The schema has to be used by the regional actors during their territorial planning. These actions are useful for the synergetic behaviors and for the harmonic territorial development. Some orientations have been defined:

- the SRCAE's implementation, which is based on an appropriated governance.
- the public awareness of the citizen, and their knowledge about climate, air and energy problems,
- a transversal development about the energy defeats, adaptation of the territorial planning to air and climate change.

1.5. The energy renovation on the existing resident sector based on low consumption

The main Alsatian objectives on the residential sector are the achievement of national targets[52] as well as the reduction of social impacts based on renovation of the existing park. In order to achieve levels of low consumption[53] by 2050, high rhythms of renovation are required. The energy efficacy on the usages must be accompanied by the installations of performed systems.

The Alsatian approach to achieve the objectives described is based on four main axes:

- the information and public awareness within the building sector has to be realized, as the first step, so as to permit the achievement and respect of the existing public programs,
- the orientation of public politics towards investments on the thermal renovation, and on issues of fuel poverty[54].
- the control of the respect of thermal regulation, based on the labialization,
- the evaluation of energy economics.

The indicators for the achievements of the object are:

- the energy diagnosis: the state of production and consumption of energies and GHG emissions into the region;
- "*Baromètre annuel Plan Bâtiment Grenelle*" CEBTP Alsace[55],

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[52] Reduction of 38% in the primary energetic consummation in 2020, Loy POPE, 13 Juliet 2005.

[53] BBC label (Batiments à bass consummation), with a consumption inferior to 104 kWh/m2/yr

[54] The Government defines fuel poverty as the need to spend more than 10% of household income to achieve adequate levels of warmth in the home and meet their other energy needs. Adequate warmth is defined as 21°C/23°C in the main living areas and 18°C in other areas.

[55] CEBTP Alsace is an institute that elaborates the data about the public and private's partner on the Building's activities, "Cellules Economiques Régionales de la Construction", National network C.E.R.C.-BTP's news".

- certificates of energy economy.

2. The territorial context

Alsace is the fifth-smallest of among the 27 regions of France in land area (8,280 km²), and the smallest in metropolitan France. It is also the seventh-most densely populated region in France and third most densely populated region in metropolitan France, having ca. 220 inhabitants per km² (total population in 2006: 1 827 253). Alsace is located on the eastern border of France, and on the west bank of the upper Rhine, adjacent Germany and Switzerland. The political, economic and cultural capital, as well as the largest city of Alsace, is Strasbourg. It is a dynamic region with an activity rate of 74%. In Alsace the main industrial sector is the tertiary sector. The industrial activities are distributed homogeneous all over the territory.

The territory is characterized by some important geography diversity: there are mountains, hills and forests. Alsace has a semi-continental climate with cold and dry winters and hot summers. There is little precipitation, in that the Vosges protect it from the west. The regional diversities characterized different energetic needs in function of physic and socio economic characteristics

Table 3.1: Calculated keys in Alsace

Surface	8 280 km² (ratio France 1,5%)
Climate	Continental (H1)
Demography	1 827 253 (ratio France 3%)
Density	221 hab. /km²
PIB par person	27 322 €
Total number of main residences	730 000 (ratio France 2,8%)
Surface of the tertiary sector m²	30,2 million (ratio France 3,5%)

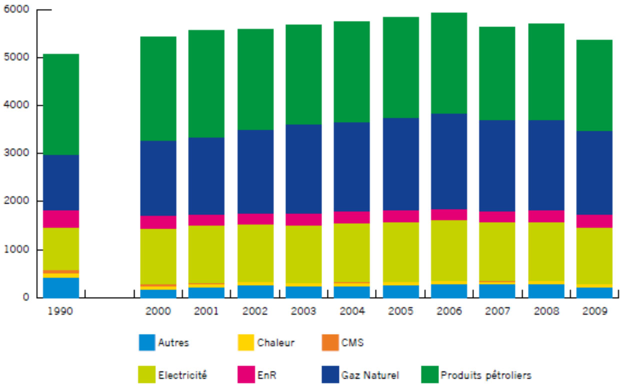
Source: Insee, Alsace region

2.1. The energy consumption

In this section, the energy situation of the region is analyzed. The study context the regional energy consumptions are considered, as a whole.

The energy consumption in Alsace represents 4% of the total national energy consumption. The regional trend of the final consumption between 1990 and 2009 is shown in the following Figure.

Figure 3.2 : Trend of the final energy consumption, divided by energy in Alsace between 1990 and 2009

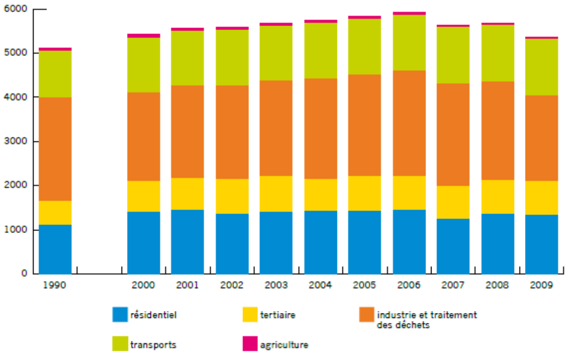


Source: CREA[56] Alsace, ASPA[57] 11110802-TD

As can be seen, this trend is following an upward line reaching a maximum in 2006, and stabilizing thereafter. In the past fifteen years, final energy consumption has increased of about 17% in Alsace It is now around 5400 ktep per year. A downwards trend seems to have begun, but it does not modify the distribution of energy consumed.

Afterwards, the trend of the distribution of consummation per sector is shown in Figure below. The year 2005 is marked by a high consumption in the industrial sector. Since then, the decline in economic activity is visible in the energy of industry. In contrast, consumption in other sectors is stabilized.

Figure 3.3 : Trend of the final consumption divided by sector in Alsace



Source: CREA Alsace, ASPA 11110802-TD

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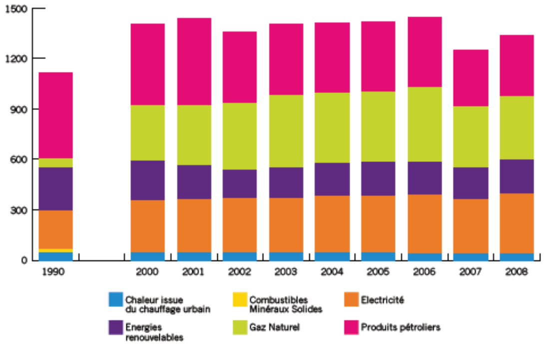
[56] CREA, Conférence Régionale de l'Energie et de l'Atmosphère

[57] ASPA, the association has the mission to generate data (measurements, emissions data and modeling) of the air quality

The energy consumption in the residential and tertiary sectors in Alsace consists of 40% of the global energy consumption in the whole region (27 TWh of primary energy)[58].

Figure 3.4 : Trend of the final consumption in the residential sector divided by energy type in Alsace between 1990 and 2009



Source: CREA Alsace, ASPA 11110802-TD

As shown below, the trend of final energy consummation presents a stabilization of gas consumption, as well as a decline in petroleum products. Renewable energy since 2002 shows an increasing trend.

This residential park in Alsace consists of 730 000 lodgments. On the complex, it is composed by: 46% of single residences, and the remaining of collective residences. 58% of buildings was been built before 1974; after the first oil choc, the need of reduction of consumption is appeared. Consequently, the buildings built after 1974 had to respect some targets of construction in order to get lower consumptions.

The periods of construction considered in this study are: before 1949, between 1949 and 1975, between 1975 and 2000 and between 2000 and 2012[59]. The percentage, in terms of number of lodgments, are represented in Figure below.

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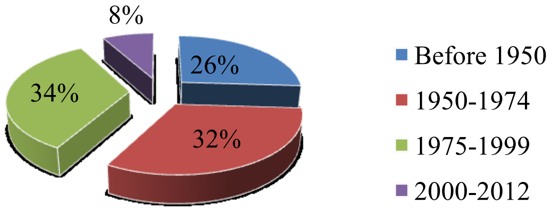
[58] Source ADEME Alsace, http://www.ademe.fr

[59] The residential sector has been divided according to years of construction in respect to the main steps of thermal regulation, and the categorization manned by ADEME.

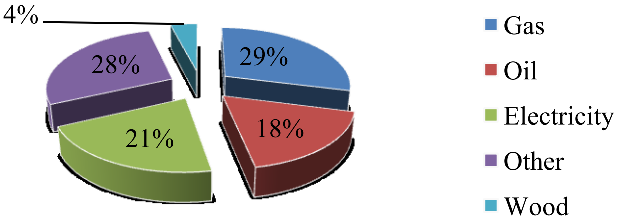
Figure 3.5: Distribution of the residential sector by period of construction in Alsace



Source: CEREN 2007

The energy consumptions estimated by CEREN in residential sector in Alsace are around 14 TWh/yr; these needs are satisfied by fuel for 14%, by gas for 29% and by electricity for 21%. The remainder is represented by PL, solar thermal, etc..

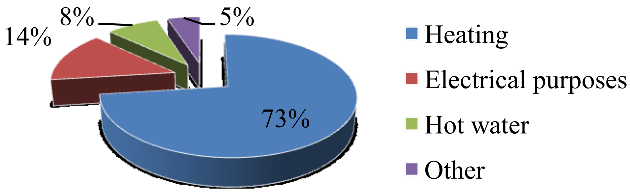
Figure 3.6: Distribution of consummations for residential sector by energy in Alsace in 2007



Source: CEREN 2007

For the building sector, a transfer from domestic oil into gas and electricity is easily measurable. These two sectors are connected within the most of the inventory, and the mix of uses and their reversibility do not show a market boundary. The analyse of energy consumption for domestic uses shows that 73% is energy used for heating, 14% for specific electricity, 8% for sanitary hot water and 5% for cooking.

Figure 3.7: Distribution of consumption for the residential sector by use in Alsace in 2007



Source: CEREN 2007

2.2. The renewable energy

Renewable energies are energies which come from natural resources such as sunlight, wind, rain, tides, waves and geothermal heat, which are renewable (naturally replenished). About 16% of global final energy consumption comes from renewable, 10% is coming from traditional biomass, which is mainly used for heating, 3.4% from hydroelectricity; new renewable (small hydro, modern biomass, wind, solar, geothermal, and bio fuel) accounted for another 3%, and are growing very rapidly. The share of renewable in electricity generation is around 19%, with 16% of global electricity coming from hydroelectricity and 3% from new renewable.

The renewable energies do not use the depleted stock of resources. As another advantage is that they do not emit GHG emissions for the production and utilization of energies or, in the case of the biomass, there is a neutral balance (the CO_2 emitted for the combustion of a plant is equal to the CO_2 used for its growth). The renewable energies are an important contribute for the diversification of energies, as well as for the security of supply, and its development is one of the privileged ways for the defeat against the climate changes. In Europe the renewable energies represent 11.7% of the final energy consumption occured in 2009, in comparison with the target of 20% in the year 2020[60].

Between 2006 and 2009, that share is increased from 9 to 11.7% of the final brute energy consumption. The European Union has to maintain this trend in order to achieve the 2020 target. In France the Law *Granelle 1* is conforming to the European directives, and it has fixed the target to 23% for renewable energies in 2020, as a final energy consumption. To achieve this objective, the share of renewable energy has to be doubled.

The main consumption sources of renewable decentralized energies are:

- Thermal energy: Biomass-wood, Warm air pumps, Solar thermal
- Electric energy: Hydraulic, Wind energy, Photovoltaic, Biogas, Biomass-wood, Geothermic

Alsace has started its energy policy in 1998. From that date on, it has gained considerably, especially for what solar energy and wood-energy is concerned. Total consumption of primary renewable energy in Alsace in 2007 amounted to 6.5% of total primary energy consumption. The follow figures represent the sharing of the contribution of renewable energy to the primary consumption in Alsace in 2007: the most developed energies are hydroelectric and wood.

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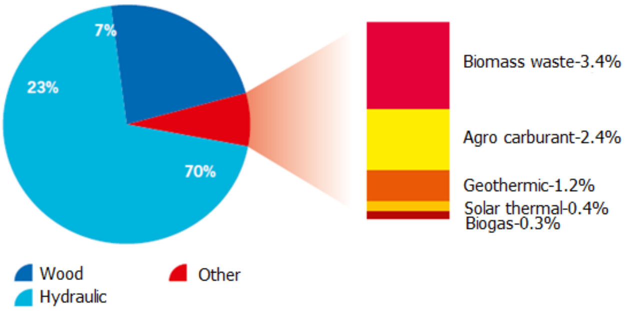
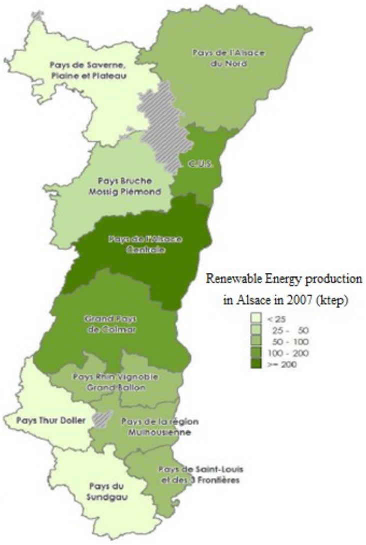
[60] Source INSEE, Énergies renouvelables, Définition, http://www.insee.fr/

Figure 3.8: Distribution of primary Energy from renewable energies in Alsace in 2007.



Source : CEREN 2007

Figure 3.9: Renewable Energy production in Alsace in 2007



Source ADEME 2007

2.3. The local biomass resource

Alsace is one of the most dynamic French region in the forest exploitation (11% of the national production derives from wood)[61]. This exploitation of woods feed both buildings and industrial sector (including paper and board). However, additional recovery is under way, supported by many political commitments in environmental and energy, as heating fuel.

Alsatian forest covers 38% of the regional surface. It is the fifth forestry French region, and it stands for a certain environmental and economic interest. The total volume of woods present in the region covers almost 81 ± 7 Mm^3, and this represents 3.4% of the

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[61] Fibois Alsace : Evaluation de la ressource bois énergie en Alsace, 2005

total national volume. 90% of wood energy potential is untapped today. Energy recovery of wood in modern boilers is a priority.

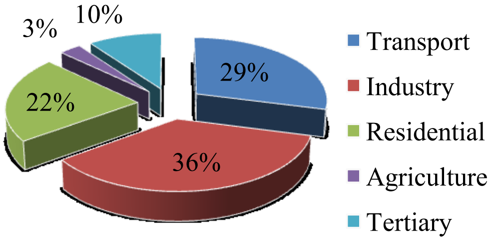
2.4. GHG emission

In France, 70% of GHG emissions were due to the use of fossil fuels in 2009[62]. The trends are very contrasting for each sector.

The emissions from the residential- tertiary are constantly increasing, between 1990 and 2009. The production of electricity and heat is covering two thirds of the emissions from energy industries. This component varies from one year to another around a stable trend, depending on climatic conditions. It is indeed an extra in addition to nuclear and hydraulic production.

In Alsace, these emissions per capita are around 7.6 tons of CO_2 equivalent per year for those related to energy, and 9.5 tons of CO_2 equivalent to total emissions is 2-3 times higher than the word average, and four times more than the level of climate stabilization. The efforts of all, since over the past 20 years, have not proved to be sufficient yet. The contribute of residential sector in Alsace, estimed by ADEME, is about 38% of GHG emissions.

Figure 3.10: Distribution of GHG emissions related to energy consumption for CO_2, in 2007 in Alsace



Source: ADEME 2005, Emissions CO_2 : accord cadre EDF – ADEME 2005

2.5. The work market

Households demand explains 59% of the market directly related to energy (32.3 milliard euros, out of a total of 54.3 milliard)[63]. This corresponds to the energy costs for housing

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[62] ADEME 2005: Emissions CO2 : accord cadre EDF – ADEME 2005

[63] ADEME, Marches, emplois et enjeu énergétique des activités liées a l'amélioration de l'efficacité énergétique et aux énergies renouvelables :situation 2008-2009 – perspectives 2010

improvement and for the acquisition of heating systems and energy efficient equipments, including passenger cars, as well as renewable energy market.

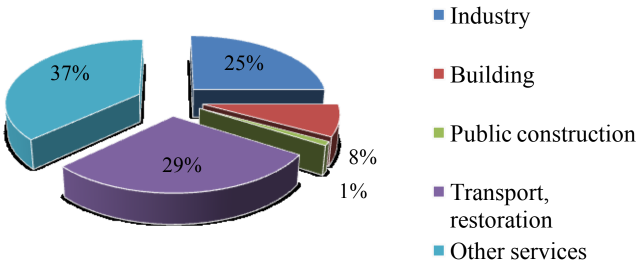
In 2009, expenditure for the development of renewable energy rose by 7%. Only the booming market of photovoltaic systems has allowed the field to maintain a positive growth. Still uncertain, if this has any connection with the work of energy control in housing or equipment performance. It seems, however, that the studied markets have continued to grow: in 2009, this would be marked by a slight increase (6%) in the interventions on buildings, while the markets of condensing boilers and performed equipments continue to record rates in double digits. These developments contrast with the decline of the global market for improved housing maintenance.

Globally, the activities that produce goods and services for the development of renewable energy and improving energy efficiency, including renewable energy market, employ the equivalent of 317,800 full-time staff in France.

In Alsace, the building sector and public works include 44,438 employees[64] (8.6% of total employment in Alsace, and 3% of employment of BTP[65] within the France metropolitan).

86% of employees of the BTP sector in Alsace works in buildings: one third of them have an activity in connection with the installation of technical equipments (water, gas, heat…); 14% of the employees in the BTP sector are engaged in the Public works, two third of them are employees belonging to the civil engineering sector.

Figure 3.11: Distribution of employees by sector, in 2010 in Alsace



Source : OREF 2012

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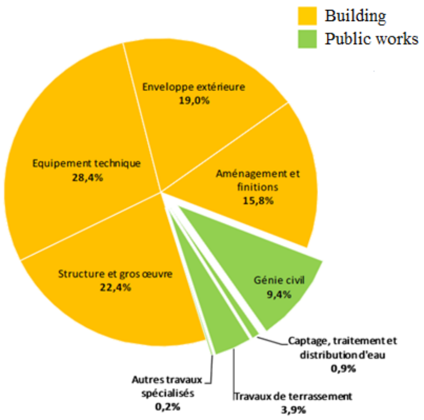
[64] OREF, observatoire régional emploi formation, Alsace, Février 2012
[65] BTP is an acronym for Buildings and Public Works (Bâtiments et Travaux Publics)

Figure 3.12 : Division of employees in the residential sector, in 2010 in Alsace



Source : Pole Emploi, OREF 2012.

4.
THE SIMULATOR

EDF Presentation

This study has been developed in EDF SA[66], which is the major French electricity utility. The study is performed within EDF R&D (research and development division of EDF), in particular, by the EnerBAT[67] department. At least 130 people are involved in this department, the "energy and building" field, having a triple mission: technological innovation (heat pump, solar, insulation, energy management...), energy prospective (sectorial studies, energy demand, forecasting...), and energy eco-efficiency support (thermal modeling of buildings, expertise...). These activities are concerning the residential and service building sectors. Dedicated to research, the EDF R&D is continually investigating new methods of construction, energy solutions, as well as more competitive and more sustainable new material. Two thirds of its projects are focused rather on short term operational performance, while one third is focused more on medium and long term.

As a European leader in the energy sector, the EDF Group is present in all major business areas, from electricity production to trading, and is improving its share within the European gas supply chain, as well. Being the main player in the French electricity market, the Group has also a solid foothold in the UK, Germany and Italy.

For what the electricity sector is concerned, the Group has the largest production park and the largest client portfolio in Europe, and is involved in targeted areas around the globe. As one of the European main network operator, it ensures a perfect balance between its regulated activities and those open to competition, via its operational model.

1. Project background

In the previous sections, this report has shown the international, national, regional and political energetic situation, that represents the background of the residential building

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[66] SA (société anonyme) means in English " Plc" (= public limited company)

[67] EnerBAT: department working on energy consumption and conservation in buildings (for Energy, Buildings and Territories within the Research and Development division of EDF

stock modeling, which has been developed in the second part of the study. The developed project would help to give an orientation to answer two main questions:

The future of energies of each region is it compatible with the new territorial needs?
Will a simple evolution or a transition of energies be adapted for each territory?

1.1. Aim and Objectives

The objective of this study consists in creating a simulator of energy efficiency on the residential housing stock. This tool has to support an educational coaching for the Regional and Departmental Communities within their politics on the main issues for energy efficiency.

The aim is the construction of quantitative and qualitative arguments, being consistent and coherent with the local context, in order to share guidance of local public policies in the energy transition.

Within the framework of the EDF R&D, the simulator is created for the "*Grand Programme Régional*"[68] dedicated to Alsace.

This innovative simulator is carried out in the form of a computer tool; the visual support enables EDF to assess the validity of its strategy and to provide a support for accompanying the actions of energy efficiency towards the residential and tertiary sectors.

This simulator is not intended to be a commercial offer, but rather a collaborative tool for development. It is located upstream the promotion offers of the EDF, generator of CEE[69] and revenue. It will support the company arguments on Eco-Energy Efficiency, it will be used to co-construct realistic targets at regional scale and, moreover, it will have the vocation of a device to be used during discussions with local communities.

1.2. Final users: locals communities

Several reasons may encourage the communities to inscribe their politics in a context of sustainable development. Concretely, this can result in the establishment of a program of local actions, as well as in an approach of eco-responsibility.

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[68] Grand Regional Programs to develop the energy efficiency at the local scale, with an adaptation of local exigencies.

[69] CEE, "Certificats d'économies d'énergie" (EEC, Certificates for energy savings), established by Articles 14-17 of Law No. 2005-781 of 13 July 2005. It lays down guidelines for program energy policy (POPE law), and it is one of the flagship policy instruments to control energy demand.

At a regional scale, sustainable development[70] can be identified as a goal of reconciliation of local issues and global problems: economic vitality, preservation of natural heritage, control of impacts on the environment, social justice, solidarity, health and quality of life.

Different reasons can lead local communities (cities, communities of municipalities, towns, agglomeration…) to inscribe their politics in this logic:

- social demand for a better life style;
- powerful synergies between environmental choices and economical impacts;
- regulatory pressure, different and complex public actions requiring a holistic and transversal vision of impacts;
- urbanization, more respectable of the environment.

The communities, to address these issues, can take different approaches:

- engagement in a program of local actions according to the Agenda 21[71];
- implementation of an eco-responsible behavior.

2. The creation of the tool

The work for the construction of the Eco-Energy Efficiency (EEE) simulator was divided into three different parts: the creation of a graphical and didactical user interface, a tool of informatics and one of calculus.

The graphical interface is the link between the user and the tools of calculus developed by the experts. It allows the choices of scenario, the different sets of hypotheses, and it shows the regional preferences. Moreover, it allows negotiation and dialogue: there is also a business purpose, while remaining within the service of territory.

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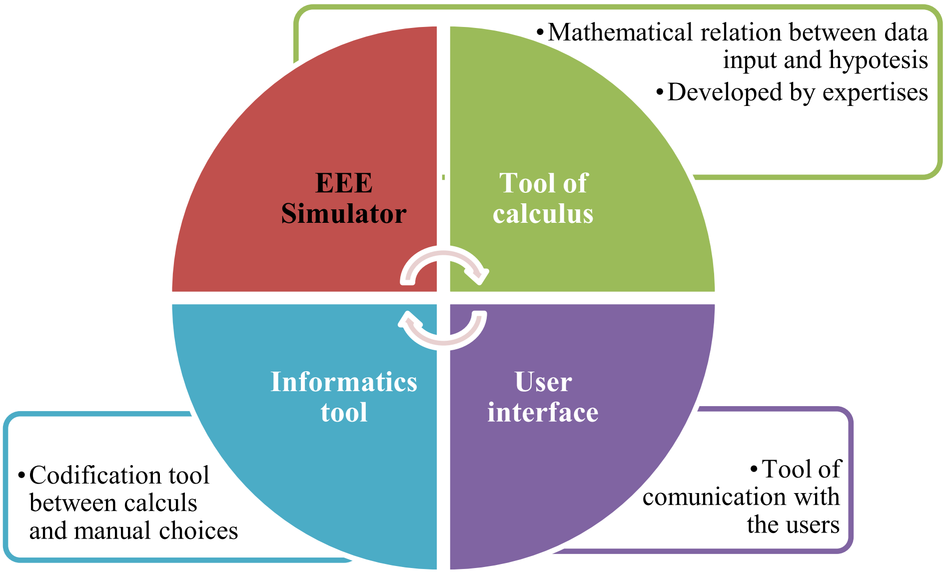
[70] Sustainable development has been defined in many ways, but the most frequently quoted definition is from Our Common Future, also known as the Brundtland Report:"Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs. It contains within it two key concepts: the concept of needs, in particular the essential needs of the world's poor, to which overriding priority should be given; and the idea of limitations imposed by the state of technology and social organization on the environment's ability to meet present and future needs.", http://www.iisd.org/

[71] Agenda 21 is a comprehensive plan of action to be taken globally, nationally and locally by organizations of the United Nations System, Governments, and Major Groups in every area in which human impacts on the environment. The Rio Declaration on Environment and Development, and the Statement of principles for the Sustainable Management of Forests were adopted by more than 178 Governments at the United Nations Conference on Environment and Development (UNCED) held in Rio de Janerio, Brazil, 3 to 14 June 1992.
The Commission on Sustainable Development (CSD) was created in December 1992 to ensure effective follow-up of UNCED, to monitor and report on implementation of the agreements at the local, national, regional and international levels. It was agreed that a five year review of Earth Summit progress would be made in 1997 by the United Nations General Assembly meeting in special session. The full implementation of Agenda 21, the Programme for Further Implementation of Agenda 21 and the Commitments to the Rio principles, were strongly reaffirmed at the World Summit on Sustainable Development (WSSD) held in Johannesburg, South Africa from 26 August to 4 September 2002. http://www.un.org/esa/dsd/agenda21/

The tool of calculus (or tool of simulation) is the heart of complex calculations, and it allows the simulation studies. Through mathematical relation between input data and hypothesis, certain outputs can be esteemed . The developed model is described in the following chapter.

The choices made by the user interface will feed the input data for the tool of calculus, which will in turn work out the desired results. In addition, this tool allows the organization and transformation of data.

Figure 4.1: Structuring of simulator of Eco-Energy Efficiency



3. Methodology development

The goal is to create a tool of simulation for the energy developments on the horizon 2030-2050 at regional scale, on the basis of assumptions derived from experts or manual choices[72].

The assumptions, organized into scenarios, allow a comparison of the possible developments and energy choices within the analyzed region.

The design of the predefined scenarios, and the simulations will be based on the information available to the R&D, as well as on the discussions with the regional partnerships:

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[72] The manual choices are made by the users to experiment different combinations of assumptions, based on their interests and needs. This aspect will be clarifies in the following chapters.

- simulations will be conducted on the basis of the tools of calculations and the expertise of EDF R&D-ENERBAT;
- data sources are taken from the last "*Recensement général de la population*[73]" conducted by INSEE[74], the "*Enquête nationale logement 2006*[75]" regionalized by CEREN[76], and the regional data from ADEME[77];
- reflection graphic will be conducted by repeating the previous studies on the design of the existing energy information.

There are three types of actions that are required for a drastically reduction of energy consumption in the residential building stock:

- saving energy, through a change of behaviors;
- energy efficiency, that is achieved through renovation, more efficient technologies and a better consumption management;
- decentralized production of renewable energy.

The impact of technical operations and the behavioral choices have been integrated within the study on the basis of discussions, negotiations and contributions of local and regional actors.

The tool of simulation has been structured into two main parts:

- the simulation based on manual selections;
- the simulation based on predetermined scenarios.

The first part has been developed in order to create a dynamic tool available to give an answer for local requirements and energy choice. The second one, to elaborate scenarios by expertises, able to give possible politics orientations.

3.1. Manual Selection

The EEE simulator based on manual selections is the part that allows the choice of expected energy targets for different uses and for a predetermined sector.

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[73] General Census of Population 2006

[74] France's National Institute of Statistics and Economic Studies (Institut National de la Statistique et des Études Économiques: INSEE) is a Directorate General of the Ministry of the Economy, Finance, and Industry. It is therefore a government agency whose personnel are government employees, although not all belong to the civil service. http://www.insee.fr/fr/default.asp

[75] National Survey Housing 2006

[76] The statistic observatory of Energy demand. www.ceren.fr

[77] French Environment and Energy Management Agency (Agence de l'Environnement et de la Maîtrise de l'Energie ADEME). It is a public agency unde the joint authority of the Ministry for Ecology, Sustainable Development and Energy and the Ministry for Higher Education and Research. Its missions are: encouraging, supervising, coordinating, facilitating and undertaking operations with the aim of protecting the environment and managing energy. www2.ademe.fr

The high potentiality of this tool allows otherwise the adaptation, of a certain number of parameters to independent and autonomy choices. This aspect has been developed according to the request of the simulator, which is a dynamic and interactive tool. This characteristic is also very useful for carrying out sensitivity analysis.

All these choices are part of the ensemble of all the simulator input parameters. In the Table, the potentials parameters chosen are shown.

Table 4.1 : Schema of the parameters taken into account for the choice.

	TYPE OF ACTION	
Type of building	✓ Single Family	
	✓ Multy Family	
Level of isolation	✓ Before 1949	✓ Non Isolated
	✓ 1949-1974	✓ Low Isolation
	✓ 1975-1999	✓ Standard Isolation
	✓ 2000-2012	✓ Low Consumption (BBC)
		✓ Passive
Heating	Energy repartition	Technology repartition
Hot Water	Energy repartition	Technology repartition
Renewable energy	Photovoltaic	Micro wind
Temperature	Valeur of interieur average temperature	

The tool of calculus has been calibrated to allow different combinations: the categories of buildings analyzed, the level of intervention on the buildings, and then the changes on energies and technologies.

Knowing for each category of buildings and their period of construction, it is possible to choose the level of isolation wished, into the model it is translated in a percentage of the matix of gains.

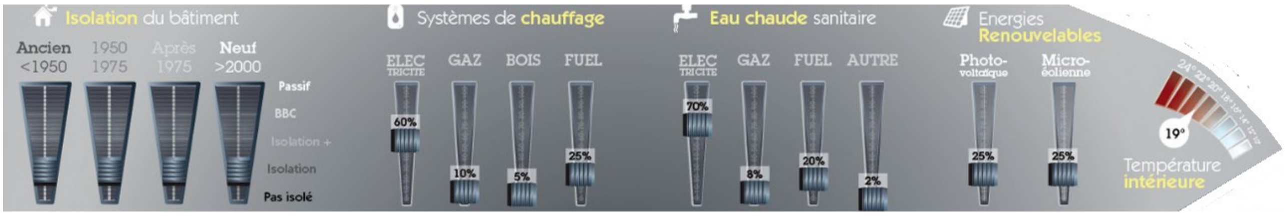
Another choice is made according to the distribution of the energy for heating and for hot water. The choice of a target on one energy has an influence on the distribution of the other one: the variation of x% of one energy implicates an inverse variation of all the others, proportionally to the existent volumes. For each type of energy, there is a choice for the distribution of the technologies. These choices are implemented within the transfer matrices.

Finally, there is a selection on the penetration rate for the renewable energy, photovoltaic and micro-wind, and for the interior temperature wished.

All the calculus are based on the starting situation in 2011, or on the results of a previous scenario choice.

A main screen example of the simulator is shown in the following Figure.

Figure 4.2: Example of a simulator screen with the manual selections available.



3.2. Predetermined scenarios

The method of scenarios is wily used for the prospective studies. This method consists of a reasoning formalization process, and it is thought looking at the future; it is a rigorous method, leaving though space for innovative scenarios, as well for an adaptable and easily appropriable methodological framework.

EEE simulator, based on predetermined scenarios, is such part that allows the choice of a scenario where the experts assumptions[78] are made. Each scenario allows to set targets for 2030 or 2050.

For this study, four scenarios have been generated:

"*Baseline*": a scenario which involves the natural evolution of the systems and energy uses; without a strong political involvement.

"*No Fuel*": this scenario incorporates a proactive policy for a systematic suppression of "fuel" energy for heating and hot water by 2050. The use of local biomass is privileged.

"*Renewable Energies*" : this scenario incorporates a proactive politic of huge renovation in buildings and a massive development of the most efficient systems, moreover, a renewable energy integrated within the buildings.

"*Factor 4*": this scenario incorporates a proactive policy of massive renovation in buildings with a high level of performance, and a massive reduction in fossil energy (oil, gas) by 2050. In addition, it includes a strong development of renewable energies integrated within the buildings, as well.

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[78] All the assumptions in this study were elaborated with the discussions of a team of experts of housing stock of EDF R&D EnerBat.

The analyses of all the hypotheses and assumptions, together with the related results, are arguments for future possible actions.

4. Results

The results are esteemed on the basis of the different input data, hypotheses and assumptions, according to different temporal scale. The results, in the forms of the indicators suggested and negotiated with the local entities, are:

- the environmental impacts (CO_2, kWh);
- the impacts on the investments for the buildings residential stock (M €);
- the impacts on energy bills for households (€);
- the impacts on employment (WFT);
- the performance measure of the chosen scenario (strengths / weaknesses).

The results are taking into consideration the global form of an interactive and educative animation for evaluating the energetic and economic impact, as well as the effect of possible energetic politics.

The final result is a compromise between an "easy" accessibility to all, the public politic sector, and the restitution of the technical indicators. These indicators are aiming at giving suggestions about the investments to be made, about the new jobs and the future energy bill for the householders.

Figure 4.3 : Example of a screen of simulator with the calculate results.

Emmissions de CO_2 (en tonnes)

Impact 12647389 sur les investissements (M€)

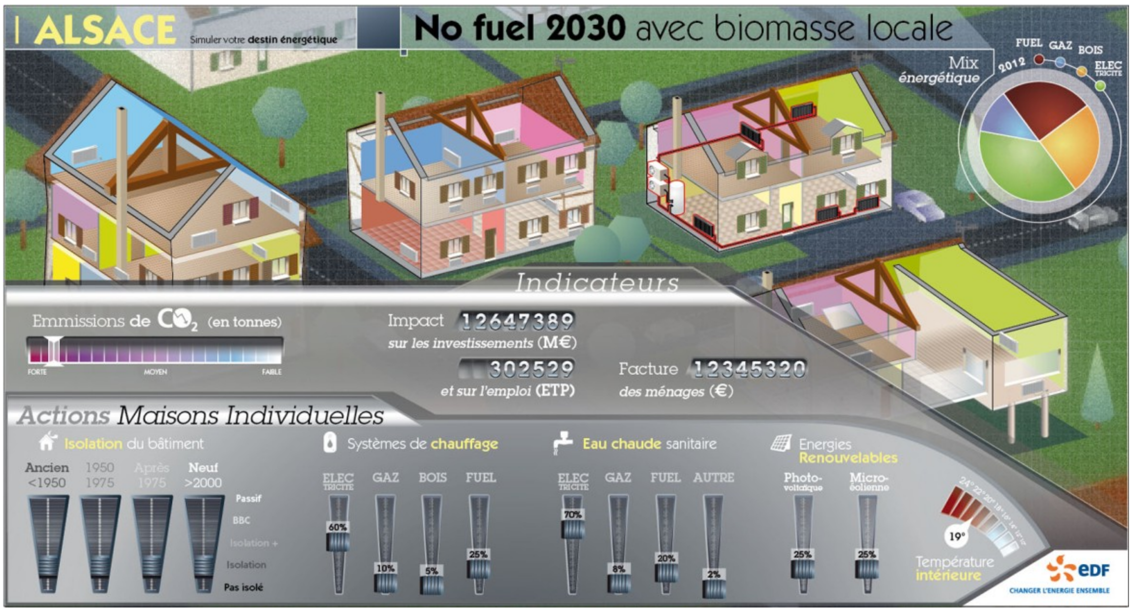
302529 et sur l'emploi (ETP)

Facture 12345320 des ménages (€)

Mix énergétique 2012

In the following Figure, an example of a simulator graphical screen is indicated. Such an e example refers to the "No Fuel" scenario, concerning Single Family dwellings (*Maisons Individuelles*). The screen is divided into the choice of actions in the lower part, and the indicators in the middle. The indicators change their values, which is based on the values of cursors of actions.

Figure 4.4 : Example of a complete simulator screen for the scenario “No fuel” for Single Family dwellings (*Maisons individuelles*).



Impact 12647389 sur les investissements (M€)

302529 et sur l'emploi (ETP)

Facture 12345320 des ménages (€)

Systèmes de chauffage: ELEC TRICITE 60%, GAZ 10%, BOIS 5%, FUEL 25%

Eau chaude sanitaire: ELEC TRICITE 70%, GAZ 8%, FUEL 20%, AUTRE 2%

Energies Renouvelables: Photo-voltaïque 25%, Micro-éolienne 25%

Température intérieure: 19°

The following section is dedicated to the explication of the detailed calculus methodology developed.

5.

THE TOOL OF SIMULATION

The heart of this study is the development of the tool of calculus; it allows the simulation of evolutions for final energy consumptions, CO_2 emissions (and other socioeconomic indicators) for residential building stock up to the desired time horizon.

The simulation allows to develop several scenarios, depending on the variation of the different energy parameters: changes in energy, technology, and type of insulation, penetration of renewable energies, interior temperature… Each of the scenario developed presents different values of indicators: budget of energy consumption, CO_2 emissions, as well as other indicators that are going to be examined in the followings section.

The energy simulation is essential for analysing the trend in the medium-long term. This simulation study has been limited to regional level, so as to take into account the existing needs of the residential building stock, all the local problems and constraints, as well as the physical and climatic characteristics of the area.

1. Methodology

The basic approach used by the model for this study is a “Bottom-up” methodology; this methodology is widely used in the prospective analysis at different territorial scale. It is based on the analysis and aggregation of disaggregated components, it needs furthermore a reliable database, and a synthesis of regional data; moreover, it implies the need of robust assumptions.

On the basis of reliable data and robust assumptions, the tool, allows sensitivity analyzes over a range of parameters, which are not fixed a priori, but they can be chosen by the user. These parameters correspond to the simulator targets described in the previous chapter.

Moreover, the model allows to aggregate all of the components for the calculation of the desired results.

The main point schema of the bottom-up method used in the study is resume in the following figure. The model is basically divided into three input families: regional data, invariable hypothesis and variable hypotheses. Through these input data and a calculus methodology, the wished results can be esteemed.

Figure 5.1: Basic schema of the Bottom-up model developed in this study.

The tool allows an analysis of the different housing stock indicators for the five principal uses: Heating, Hot Water, Air Condition, Cooking and Specific Electricity.

2. The database

2.1. General Census of the Population 2006

The general census of the population by INSEE provides access to the statistical data concerning the characteristics, the location of people and buildings, as well as the projections of different natures.

For this study, the projection of population estimated by “Omphale[79]” has been considered. “Omphale” is a complex application consisting of a theoretical model for population projection, demographic database, demographic analysis technique and tools for buildings scenarios for the future.

“Omphale” projections are based on the “component method”; this method follows a pyramid of age from three different components: births, deaths and migration.

2.2. Regional Consumption, CEREN

Regional consumption data are classified by CEREN per period of construction of housing and consumption of kWh for different uses (heating, cooking, hot water ...), energy expenditure in euros, depending on the type of buildings (single or collective), type of combustible (electricity, gas, fuel..) and whether it belongs to the type of HLM houses[80].

Consumption and average costs per square meter (kWh / m² and Euro / m²) are calculated by weighting the surface of the housing and the household population consumers, only. This weighting with the housing surface allows to take into account the surface effect: consumption per m² is inversely proportional to the surface.

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[79] OMPHALE, « *Outil Méthodologique de Projection d'Habitants, d'Actifs, de Logements et d'Élèves* » (Methodological tool Projection of Population, Asset, and Accommodation of Students)

[80] HLM (*habitation à loyer modéré*), French for "housing at moderated rents" or "rent-controlled housing", is a form of subsidised housing in France. There are approximately four million such residences, housing an estimated 12 million people — nearly one-fifth of the population of France.

The “Housing” survey collects energy consumption data for household, not in a form of physical quantity but rather in Euros per energy consumed (except for wood, whose amounts are collected in m^3). From the energy bill in Euros of each energy reported by householders, the corresponding consumption in kWh is calculated. The consumption computational models from bills are determined using the information from the accumulated consumption panel over five years: 2002, 2003, 2004, 2005 and 2006, so as to have sufficient observations. At these rates the consumptions in 2006 are applied.

The estimated heating consumption

Electricity: from the electricity consumption of all uses, the determination of electricity consumption for heating has been calculated in two stages: the electricity consumptions for cooking, hot water and specific uses are estimated, household by household, according to their characteristics (number of people living in, CSP, housing surface, data construction and household income, mix of cooking energy). These estimates are derived from studies made by CEREN “Unit consumption of gas and electricity per equipment used in main homes” and “Competitiveness of heating and hot water supply”. Heating consumption is obtained by subtracting the total electricity consumption (all uses) from the consumption obtained by step 1.

Gas: the consumptions of cooking and hot water (centralized or independent device) are estimated using the same method as in the case of electricity.

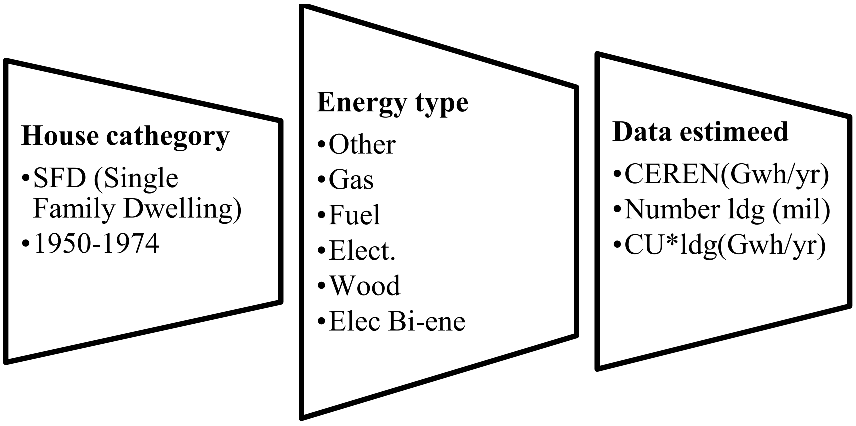
Fuel and Wood: the consumption of hot water (produced by boilers) is estimated assuming that it features equal 1.5 times higher than that of natural gas. No studies are available for direct estimations.

Estimation of weighted and corrected unit consumption

Based on the estimated and published data by CEREN, the weighted average consumption has been calculated for this study. The weighting is based on the classification of buildings stock construction years, taking into consideration the values corrected to account for bioenergies.

One example are those houses classified in “*Maison Fuel*”, which play also a rule on the consumption of gas heating.

Table 5.1 : The table is showing an example of the structure of final energy consumption for building stock, divided by type of energies and period of construction, 2006[81].



3. Regional Input Data

Input data are: population, distribution of consumption in the housing stock, needs for heating and domestic hot water, climate within the zone of interest, and a series of other assumptions, divided into two groups: robust and variables assumptions[82].

The regional population and its evolution have been estimated by INSEE, as well as the projection model "Omphale 2010", considering 0.54% growth rate per year.

The existing buildings stock has been divided into Single-Family and Multifamily; each of these categories has been subdivided according to the construction year: before 1949, between 1950 and 1974, between 1975 and 1999, between 2000 and 2012. These subdivisions has derived from the buildings repartition aggregations conducted by CEREN.

The number of regional buildings and their evolution has also been estimated by INSEE model, "Omphale 2010", considering 1.04% growth rate per year.

Important for the production of renewable energies (photovoltaic and solar thermal) is the identification of climatic zones. The national territory can be subdivided into two types: one type depending on the solar power and the other on the wind conditions. The first category divides France into three zones: H1, H2, H3[83], and the second into five[84].

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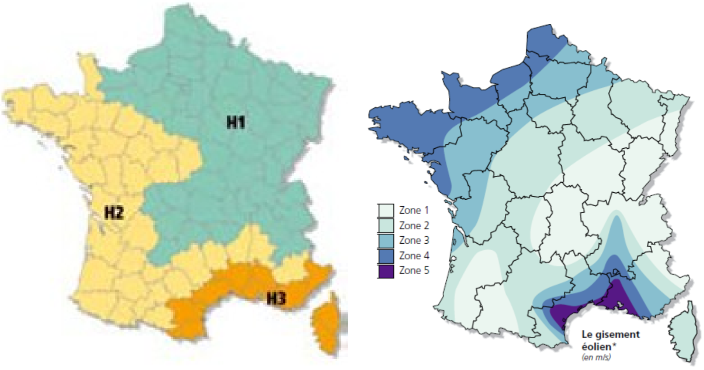
[81] Data not available.

[82] This classification will be clarified in the follow paragraph: the first set are the fixed hypotheses (e.g. evolution of performance…), the second one are the hypotheses that the user or the choice of scenario can modify (e.g.: subdivision by energy of building sector).

[83] JORF n°121 du 25 mai 2006 page 7747 texte n° 14, Arrêté du 24 mai 2006 relatif aux caractéristiques thermiques des bâtiments nouveaux et des parties nouvelles de bâtiments, http://www.rt-batiment.fr/

The following Figure shows the national maps subdivided into climatic zones according to solar resistance and wind condition. This study is considering the area of Alsace, which is referring to the H1 climatic zone, areas 1-2 (low solar resistance and low wind conditions).

Figure 5.2 : Map of France, showing the climatic zones according to solar power (H1, H2, H3), and wind patterns (Zones 1-5)



Source: Rt-batiment and ADEME, 2009

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[84] ADEME, “Les énergies renouvelables: dans l’air du temps, l’énergie éolienne », Février 2009, http://www.ademe.fr

Table 5.2 : Input data used by the model

	DATA IMPUT
Population	[Number of inhabitants]
Subdivision existent buildings	Number of buildings divided by: ✓ type of building (Single-Family and Multy Family), ✓ year of construction (before 1949, between 1950 and 1974, between 1975 and 1999, between 2000 and 2012.), ✓ used energy (Gas, Electricity, Fuel, Wood, Other).
Needs of Heating and Hot Water	[kWh/house/yr]
Climatic Area	✓ Solar strength (H1, H2, H3), ✓ wind patterns (Zone 1-5).
Robust Hypotheses	✓ Index of incidence of new buildings ✓ The evolution of performance of systems of heating, Hot Water and Cooling ✓ Index of evolution of needs of Hot Water and Cooling ✓ The rate of equipment of Cooling and Cooking ✓ The consumption of equipped household (MWh) for the Cooling, Cooking, Specific Electricity ✓ The energy prices
Varibles Hypotheses.	✓ The insulating level ✓ The target of subdivisions by energies and technologies (Electricity Joule & Electricity Thermodynamic, Micro cogeneration (CHP) &Gas Condensation, Wood Pellet, Wood Stove, Fuel Low Temperature & Fuel Condensation), by old and new buildings, for heating and hot water. ✓ The renovation rate of buildings ✓ The penetration rate of renewable energies: Solar Thermal, Micro wind and Photovoltaic ✓ The variation of interior temperature

3.1. Needs assessment

The values of regional needs of heating in 2006 have been estimated based on the available knowledge. This section will present the classic approach for determining the needs, and the approach used in this study.

The energy consumption of buildings, or energetic index, is defined as the annual consumption of energy for heating in a dwelling, subdivided by the heated surface.

$$Energetic.Index = \frac{Energy.consumption}{Surface.of.reference} \qquad (1)$$

The energy consumption is indicated in kilowatt-hours per year (kWh / year), and the needs of heating and for the production of hot water are derived by these consumptions; the surface of reference is indicated in square metres (m^2).

The energy index, and therefore the needs, are power per unit area, expressed in kilowatt-hours per square metre per year (kWh / (m^2.yr)).

The energy needs of a building are depending not only on the building thermal performance (insulation, exposed surface, contribution of passive solar,…), but also on the interior temperature desired by the people living in.

The determination of the thermal needs for a building can be calculated using the formula which links the global coefficient of dispersion G ($W/m^3/°C$), the volume V of the building taken into consideration (m^3), and the difference in temperature between inside and outside the building ΔT (°C):

$$B = G * V * \Delta T \qquad (2)$$

The coefficient G depends on the thermal quality of walls, windows, roofs, basements and ventilation.

In order to finalize this study, the needs have been divided according to uses, the latter are estimated indirectly on the basis of the available data. The values of the needs have been estimated according to the class of efficiency[85] for the different categories: uses, energies and technologies.

The data analyzed and used for the calculus are:

- the unit regional consumption for use, period of construction of buildings and energy, in 2006; estimation by CEREN,

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[85] EU Directive 92/75/EU established an energy consumption labeling scheme. The Energy Labelling Directive requires that appliances be labelled to show their power consumption in such a manner that it is possible to compare the efficiency with that of other makes and models.

- the system performances,
- the knowledge of EDF R&D's expertise.

The first step to follow for the estimation of the needs consists in evaluating the rank value for each efficiency class, based on the energy consumption given by CEREN 2007.

Each period of construction presents a wide range of values for energy consumption: as a matter of fact, this may depend on different factors (material, orientation, equipments…); all of these disaggregation of factors are difficult and complex to model on a regional scale. Therefore, for each period of construction a split between Effective and Ineffective buildings only, has been considered. This method is aiming at keeping into consideration the different level of performance in buildings, due to building and system renovation works.

Based on the final energy consumption for each period, the Effective and Ineffective consumptions have been estimated. To this aim, firstly, the average values among consumptions of residential building stock for heating, according to CEREN 2007 data, have been considered; the reference class is represented by building built after 1999. Then, the percentage of housing consumption showing values above and below these average values has been analyzed, so as to estimate the rank of variation in function of the efficiency class. The buildings showing values above the average are classified as Efficient, the ones showing the values below the average are classified as Inefficient.

Table 5.3: Values as a percentage of houses, where heating energy consumption per m^2 is less than the average heating consumption per m^2 in buildings built after 1999.

After 1999 (*Period of reference*)	50%
Before 1915	19%
1915-1948	19%
1949 – 1974	27%
1975-1981	28%
1982 -1989	33%
1990-1998	42%

Source: CEREN 2007

Finally, the heating needs are estimated according to the products between heating consumption by building construction period and by the level of efficiency, and the values of the systems performance.

$$Need = Consumption \times Performance \tag{3}$$

In the following Table, an example of the average weighted needs regarding all the periods of construction for the single family dwelling stock is reported.

Table 5.4 : Average needs for single family dwellings (kWh/house/yr)

		Ineffective	**Effective**
Electicity	*Joule*	6,7	4,6
	Thermodynamic	6,7	4,6
Gas	*Micro-cogeneration*	13,4	10,8
	Condensation	13,4	10,8
Wood	*Pellet*	15,7	13,7
	Stove	15,7	13,7
Fuel	*Low Temperature*	17,9	14,7
	Condensation	17,9	14,7

3.2. Invariable hypotheses

This first family of assumptions is established on the basis of expertise's knowledge and the existing studies.

The basic assumptions that are taken into account in this study, independent by their scenarios are:

- index of incidence of new buildings (INSEE Omphale 2010),
- evolution of the system performances: heating, hot water and air condition (assumptions by EDF R&D),
- index of need evolution: hot water and cooling (formula by CSTB[86], where an almost stable evolution as a hypothesis, is considered),
- rate of equipment for cooling and cooking,
- consumption per equipped household (MWh) for cooling, cooking, specific electricity, (CEREN 2007),
- energy prices (SeOS[87], assumption of invariance in the price evolution)

3.3. Variable hypotheses

This second family of hypotheses is depending on the different scenarios. These parameters could assume a range of values based on politics and future choices regarding the building sector.

These assumptions are:

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[86] CSTB, "Centre Scientifique et Technique Building" has four key activities: research, expertise, evaluation, and dissemination of knowledge, organized to meet the challenges of sustainable development in the world of construction. His field of expertise covers construction products, buildings and their integration into neighborhoods and cities. http://www.cstb.fr/

[87] SOeS, Service de l'observation et des statistiques, Ministère de l'Ecologie, du Développement durable, des Transports et du Logement.

- the insulation level is given by the thermic performance level in buildings. The levels of insulation are divided into five categories, based on unit consumptions:

    - no insulation,
    - low insulation,
    - standard insulation,
    - low consumption (BBC[88]),
    - passive[89].

- subdivision target according to energies and technologies within old and new buildings, for what heating systems and hot water systems are concerned:

    - Electricity Joule & Electicity Termodynamic,
    - Micro cogeneration Gas & Gas Condensation,
    - Wood pellet, Wood stove,
    - Low Temperature Fuel & Fuel Condensation

- renovation rate in building sector;
- penetration rate for renewable energies:

    - Solar Thermal,
    - Micro wind,
    - Photovoltaic.

3.3.1. The insulation level:

A thermal insulation consists in the reduction of heat transfer (the transfer of thermal energy between objects of different temperature), that is between objects in thermal contact or in range of radioactive influence. A thermal insulation can be achieved thanks to special engineering methods or processes, as well as by suitable object shapes and materials. Thermal insulation in buildings is an important factor for achieving thermal comfort for their occupants. Insulation reduces unwanted heat loss or gain and can reduce energy demands for heating and cooling systems.

The Building insulation depends on: roof Insulation, under deck Insulation, over deck Insulation, wall Insulation and false ceiling.

In this study, the insulation level in the residential building stock has been simplified and categorized into five classes. These classes have been established based on the type of building (year of construction and average energy demand).

The initial situation concerning the residential building stock in Alsace takes into consideration the following: all of the buildings built before 1975 are “Non isolated”, the buildings between 1975 and 1999 are “Isolated” and the buildings between 2000 and

---

[88] BBC (“Batiments a Bas consummation”)

[89] These subdivision has been elaborated with the expertise of EDF R&D.

2012 "Isolated +". These categories are macro categories, where the whole behavior of the regional building stock is tried to be considered; following a renovation, buildings can reach a high level of insulation. Two levels have been considered: BBC and Passive. These two building performance labializations have been defined following the thermal performance regulation.

BBC: Low consumption building: it is a label ("*Bâtiment de basse consommation énergétique*") created in may 2007. The energy demands are set to 50 kWhEP/m^2 (kWhEP=kWh for primary energy). These demands are corrected according to a of rigorous climatic coefficient, dependent on the climatic area. The demand values show a variation range between 40 and 70 kWhep/m^2*yr. The consumptions considered within the calculus regard heating, hot water, cooling and specific electricity.

Passive or zero carbon house: it is a standard requiring high energy efficiency standards (where energy demand for space heating is expected to be around 40 kWh/m^2, compared to an average of around 200 kWh/m^2 in the existing stock).

3.4. Predetermined scenarios

In this study four scenarios have been created[90]. The choice of a scenario has been calibrated in order to identify the main issues and the possible ranges within regional actions. This section is showing the following scenarios:

- Scenario «Baseline»
- Scenario «No fuel»
- Scenario «Renewable energies»
- Scenario «Factor 4»

3.4.1. Scenario « Baseline »

This scenario is characterized by a low rate of renewal, as it is nowadays, 1.5 % per year; this means 45% of renovated buildings by 2050.

The building sector is a homogeneous one, and fully renovated at "Isolation Standard" level. This sector is responsible for a 30% reduction in energy need for buildings built before 1975, and 50% reduction in energy need for new sector ("BBC" level).

Concerning the energies, those buildings built before 2012 appear to preserve a penetration structure of energies for what heating and hot water is concerned, showing a diffuse use of combustible fossils and a low use of wood. The changes in systems and energies are scarce, and this is due to the natural trend of evolutions and aging of the systems.

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[90] Hypotheses elaborated by the EDF expert

New buildings show the same energy penetration rate for heating and hot water as the buildings built between 2000 and 2012

The incidence of renewable integrated energy for buildings lies marginal, both for new and old constructions.

3.4.2. Scenario «No fuel»

This scenario is characterized by a systematic suppression of "Fuel" energy for heating and hot water up to the horizon 2050, where local biomass is favoured.

The renewal rate for buildings is 2.6% per years (totalling a 60% renovation by 2050). The building sector looks to be homogeneous and all renovated for what "Isolation standard" level is concerned; it can be accountable for a 30% reduction in energy need for buildings built before 1975, and 50% in energy need for new sector (level "BBC"). This scenario does not consider a strong renovation policy for buildings.

This scenario is based on a massif change on energies and technologies. The fuel is suppressed and is replaced by other energies (electricity, gas, and wood). These changes are to be associated with those occuring in high performance technologies: systems of micro-cogeneration, hot air pumps thermodynamics.

The incidence of the renewable integrated energy for buildings lies constantly marginal, both for new and old constructions. On the contrary, the use of local biomass for heating is remarkable.

3.4.3. Scenario «Renewable energies»

This scenario integrates remarkable building renovations and a massif development for high performance systems, as well as for renewable energies integrated to buildings.

The buildings show 2.82% renewal rate per year (reaching 85% renovation by 2050). The building sector appears to be homogeneous and entirely renovated at "Isolation +" level; it is accountable for 50% reduction in energy needs for buildings built before 1975, 30 % for buildings built before 2000 and 60% for new sector.

This scenario is characterized by an exploitation of wood heating over the local available resource. The changes of energy are associated to changes of technologies: micro-cogeneration systems, hot air pumps thermodynamics. Moreover, 50% of the hot water is produced by solar energy.

The use of renewable energy is greatly developed: 50 % of single family dwellings, and 33% of multifamily dwellings in new and old buildings are equipped with photovoltaic panels; the penetration rate for wind energy is 15 %, on average.

3.4.4. Scenario «Factor 4»

This scenario integrates a great renovation policy for buildings, showing high performance levels, massif reduction in fossil energies (fuel, gas) to horizon 2050. The scenario is also characterized by a development for renewable energies integrated to buildings.

The buildings show a 3.28% renewal rate per year (99% renovation is expected by 2050). The building sector appears to be homogeneous and fully renovated at "BBC" level; this sector is accountable for 80% reduction in energy need for buildings built before 1975, 50 % for buildings built before 2000 and 80% for new sector.

This scenario is considering a renovation policy for buildings, which implies a massif reduction in heating consumptions.

The energies gas and fuel are replaced by biomass and electricity. The local biomass for heating is exploited over the local available resources. The changes of energy are associated to changes of technologies: micro-cogeneration systems, hot air pumps thermodynamics. Moreover, 30% of hot water is produced by solar energy.

The use of renewable energy is greatly developed: the photovoltaic penetration rate accounts for 20 % in old buildings and 33% in new ones. The wind energy shows a 10% penetration rate, in average.

4. Calculus method

According to the uses (heating, hot water, cooling..), different approaches have been used for the calculus of simulations. The focus has been led over the details regarding the calculus for heating and hot water; cooling, specific electricity and cooking have been discussed in a more simplified manner. The choice of the detail level has been carried out weighting the total consumption according to the uses and the available data.

Firstly, the study has been focused on the general method used for simulating heating and hot water. The main point was the construction of two matrices: the transfer and the gains; allowing so the possibility to switch from the various energies, technologies and efficacy in the building stock. Secondly, this section analyses in details the methodology for the evaluation of future energy consumption for each use.

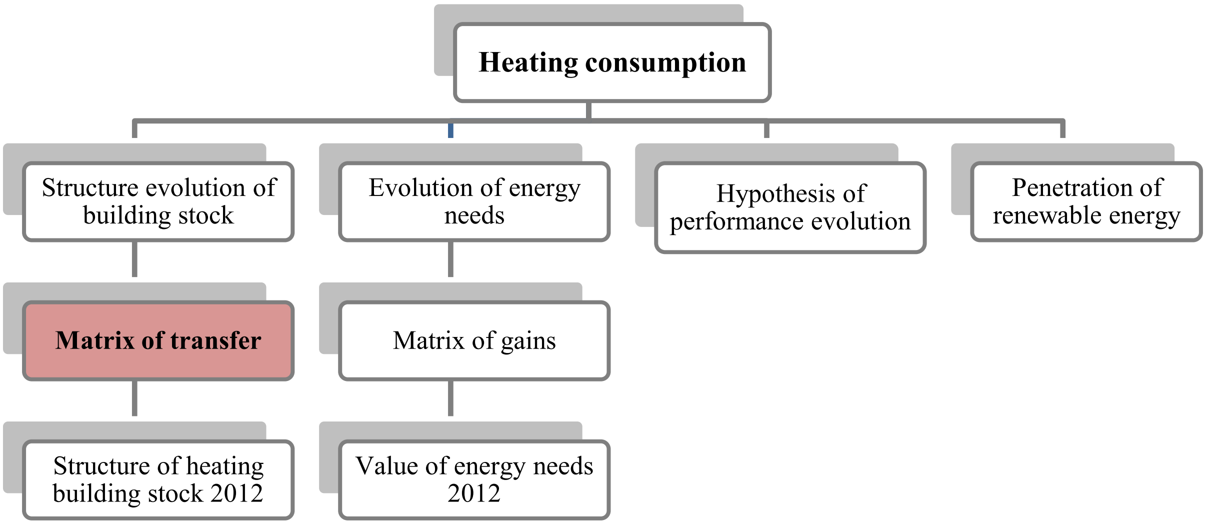
4.1. The matrix of transfer

In this study, the matrix of transfer has been developed in order to permit the switch from the various energies, technologies and performances for buildings in a long term horizon. It is a function of changes among energies, technologies and renovation rate in buildings.

It allows the distribution of the new structure for the residential building stock as one desired target: the structure is based on used energies, technologies and efficiency categories (effective and ineffective).

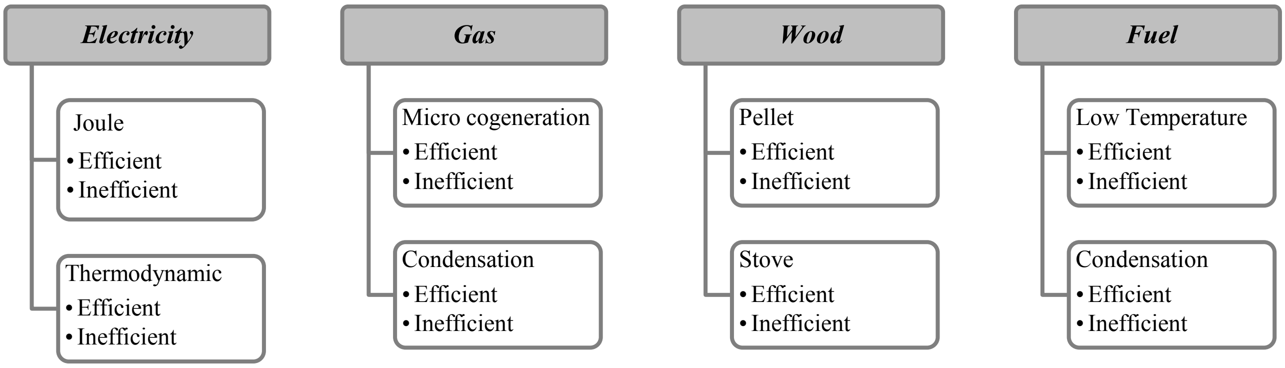
The explanation for the creation of the matrix is given considering the example of the heating systems. The following graph is showing schematically the calculation main steps for the consumption of the heating systems.

Figure 5.3 : Schema of calculus for the consumptions of the heating systems



The matrix is estimated according to the two types of houses (Single and Multifamily) and considering the four periods of the building stock construction. Each matrix is divided into five types of energies (Electricity, Gas, Fuel, Wood and Other) and for each one there are two types of energies available. The Figure shows the details of such a division.

Figure 5.4 : Transfer matrix structure for the heating system



This matrix is calculated according to three intermediary matrices:

- matrix of substitution between energies;
- matrix of changes in technologies;
- matrix of renovation rate for buildings

The first matrix is the one which considers the substitution among energies; it allows the change of energy, and is divided among Electricity, Gas, Fuel, Wood and Other. Starting from the initial subdivision into the number of houses per energy type, it can be seen how the different energies will be subdivided in terms of house number percentage.

Table 5.5 : Matrix of substitution 2010-2050 between the energies regarding the “No Fuel” scenario, hypotheses EDF R&D

	Electricity	**Gas**	**Wood**	**Fuel**	**Other**
Electricity	100%	0,0%	0,0%	0,0%	0,0%
Gas	1,6%	94%	4,1%	0,0%	0,0%
Wood	0,0%	0,0%	100%	0,0%	0,0%
Fuel	27,7%	0,0%	72,3%	0%	0,0%
Other	14,5%	0,0%	37,8%	0,0%	48%

The first column represents the initial state, and on each row is shown the new energy distribution. The percentage represents the total number share of houses for the analyzed category.

Such energy distribution, in the horizon 2030-2050, is predetermined by scenarios or manual choices (as explained in the previous section). If a target energy to 2030-2050 is imposed manually, the other energies will be proportionally divided according to the existing building repartition. Then, the variation in percentage of buildings changing energies and the proportion in which they are distributed is estimated. The columns in the matrix represent the states (t) and the lines represent the distribution on the instant (t + Δt); the values on the diagonal are representing the percentage of energy remaining invariant between t and t + Δt, the other values, on the same line, represent the new energy distribution up to the year t + Δt. The total sum of each line is equal to 100%.

The matrix of changes of technologies, that is the second matrix, allows to take into consideration the switch between technologies. For each analyzed energy two different technologies are considered, according to each of the following energy types:

- Electricity: Joule or Thermodynamics;
- Gas: Condensation or Micro Cogeneration;
- Fuel: Low temperature or Condensation;
- Wood: Pellets or Stoves.

This matrix shows the variation for the repartition of the technologies between the instant t (rows) and the instant t+Δt (lines).

Table 5.6 : Matrix of changes of technologies 2010-2050, for the scenario "No Fuel", hypotheses EDF R&D

		Joule	*Thermodynamics*
Electricity	*Joule*	0%	100%
	Thermodynamics	0%	100%
		Micro cogénération	*Condensation*
Gas	*Micro cogeneration*	100%	0%
	Condensation	29%	71,40%
		Pellets	Stove
Wood	*Pellets*	100%	0%
	Stove	80%	20%
		Low Temperature	*Condensation*
Fuel	*Low Temperature*	0%	100%
	Condensation	0%	100%

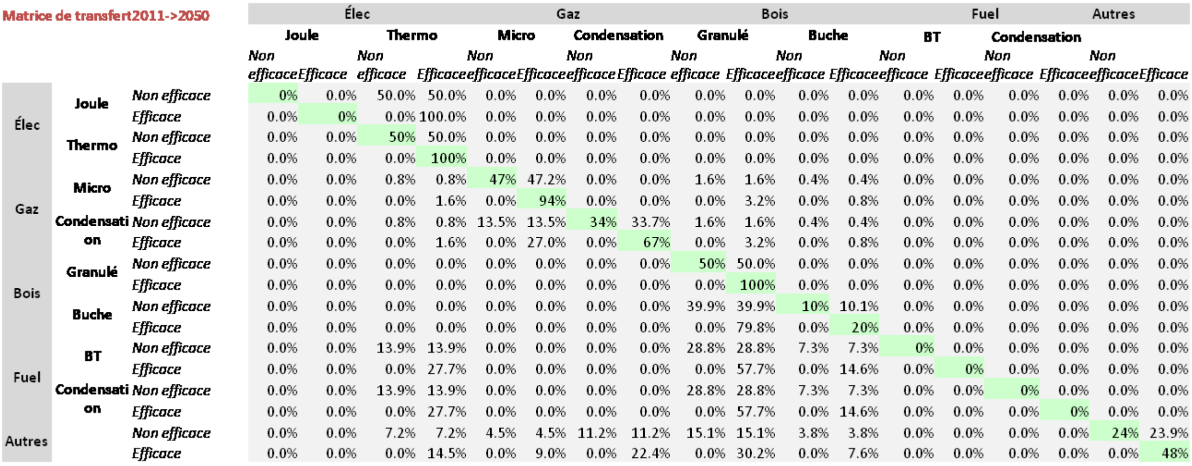
Finally, the third matrix concerns the building renovation rate. It represents the percentage of house number showing an interest in some changes. This percentage switches between efficient and inefficient categories.

Table 5.7 : Matrix of renovation rate 2010-2050 for buildings, according to "Baseline" scenario, hypotheses EDF R&D

	Inefficient	**Efficient**
Inefficient	50,0%	50,0%

The matrix of transfer is the product of these three matrixes.

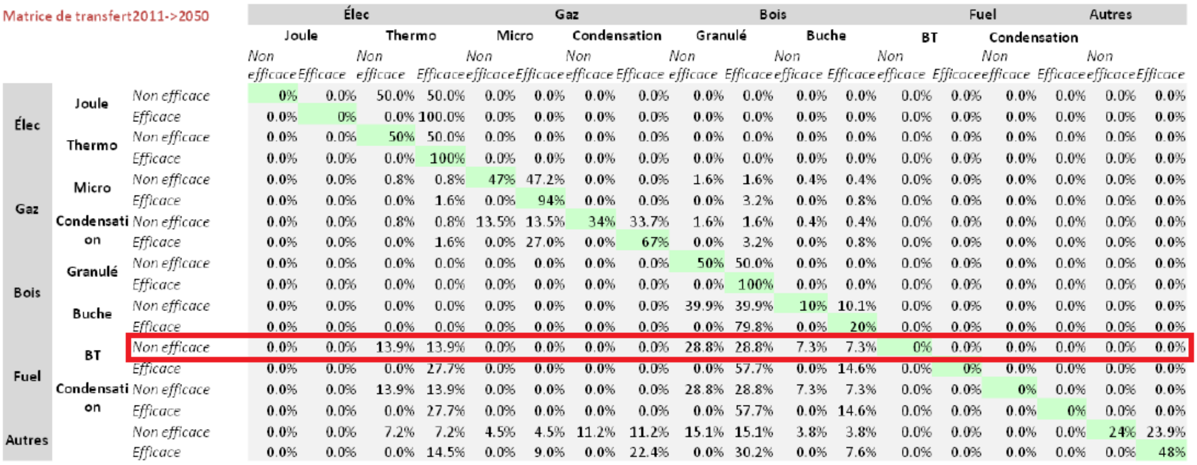
Table 5.8 : Matrix of transfer 2011-2050 for single family dwellings, according to «No Fuel » scenario, based on EDF R&D hypotheses.



Matrice de transfert2011->2050			Élec				Gaz				Bois				Fuel				Autres	
			Joule		Thermo		Micro		Condensation		Granulé		Buche		BT		Condensation			
			Non efficace	Efficace	Non efficace	Efficace	Non efficace	Efficace	Non efficace	Efficace	Non efficace	Efficace	Non efficace	Efficace	Non efficace	Efficace	Non efficace	Efficace	Non efficace	Efficace
Élec	Joule	Non efficace	0%	0.0%	50.0%	50.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		Efficace	0.0%	0%	0.0%	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Thermo	Non efficace	0.0%	0.0%	50%	50.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		Efficace	0.0%	0.0%	0.0%	100%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Gaz	Micro	Non efficace	0.0%	0.0%	0.8%	0.8%	47%	47.2%	0.0%	0.0%	1.6%	1.6%	0.4%	0.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		Efficace	0.0%	0.0%	0.0%	1.6%	0.0%	94%	0.0%	0.0%	0.0%	3.2%	0.0%	0.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Condensation	Non efficace	0.0%	0.0%	0.8%	0.8%	13.5%	13.5%	34%	33.7%	1.6%	1.6%	0.4%	0.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		Efficace	0.0%	0.0%	0.0%	1.6%	0.0%	27.0%	0.0%	67%	0.0%	3.2%	0.0%	0.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Bois	Granulé	Non efficace	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	50%	50.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		Efficace	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Buche	Non efficace	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	39.9%	39.9%	10%	10.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		Efficace	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	79.8%	0.0%	20%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Fuel	BT	Non efficace	0.0%	0.0%	13.9%	13.9%	0.0%	0.0%	0.0%	0.0%	28.8%	28.8%	7.3%	7.3%	0%	0.0%	0.0%	0.0%	0.0%	0.0%
		Efficace	0.0%	0.0%	0.0%	27.7%	0.0%	0.0%	0.0%	0.0%	0.0%	57.7%	0.0%	14.6%	0.0%	0%	0.0%	0.0%	0.0%	0.0%
	Condensation	Non efficace	0.0%	0.0%	13.9%	13.9%	0.0%	0.0%	0.0%	0.0%	28.8%	28.8%	7.3%	7.3%	0.0%	0.0%	0%	0.0%	0.0%	0.0%
		Efficace	0.0%	0.0%	0.0%	27.7%	0.0%	0.0%	0.0%	0.0%	0.0%	57.7%	0.0%	14.6%	0.0%	0.0%	0.0%	0%	0.0%	0.0%
Autres		Non efficace	0.0%	0.0%	7.2%	7.2%	4.5%	4.5%	11.2%	11.2%	15.1%	15.1%	3.8%	3.8%	0.0%	0.0%	0.0%	0.0%	24%	23.9%
		Efficace	0.0%	0.0%	0.0%	14.5%	0.0%	9.0%	0.0%	22.4%	0.0%	30.2%	0.0%	7.6%	0.0%	0.0%	0.0%	0.0%	0.0%	48%

The first three rows of the represented matrix concern the energy, technology, and efficiency solutions analysed, and in each line their evolutions to horizon t+Δt is represented.

Table 5.9 : Detail of the matrix of transfer 2011-2050 for single family dwelling according to «No Fuel » scenario.



Matrice de transfert2011->2050			Élec				Gaz				Bois				Fuel				Autres	
			Joule		Thermo		Micro		Condensation		Granulé		Buche		BT		Condensation			
			Non efficace	Efficace	Non efficace	Efficace	Non efficace	Efficace	Non efficace	Efficace	Non efficace	Efficace	Non efficace	Efficace	Non efficace	Efficace	Non efficace	Efficace	Non efficace	Efficace
Élec	Joule	Non efficace	0%	0.0%	50.0%	50.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		Efficace	0.0%	0%	0.0%	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Thermo	Non efficace	0.0%	0.0%	50%	50.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		Efficace	0.0%	0.0%	0.0%	100%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Gaz	Micro	Non efficace	0.0%	0.0%	0.8%	0.8%	47%	47.2%	0.0%	0.0%	1.6%	1.6%	0.4%	0.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		Efficace	0.0%	0.0%	0.0%	1.6%	0.0%	94%	0.0%	0.0%	0.0%	3.2%	0.0%	0.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Condensation	Non efficace	0.0%	0.0%	0.8%	0.8%	13.5%	13.5%	34%	33.7%	1.6%	1.6%	0.4%	0.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		Efficace	0.0%	0.0%	0.0%	1.6%	0.0%	27.0%	0.0%	67%	0.0%	3.2%	0.0%	0.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Bois	Granulé	Non efficace	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	50%	50.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		Efficace	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Buche	Non efficace	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	39.9%	39.9%	10%	10.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		Efficace	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	79.8%	0.0%	20%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Fuel	BT	Non efficace	0.0%	0.0%	13.9%	13.9%	0.0%	0.0%	0.0%	0.0%	28.8%	28.8%	7.3%	7.3%	0%	0.0%	0.0%	0.0%	0.0%	0.0%
		Efficace	0.0%	0.0%	0.0%	27.7%	0.0%	0.0%	0.0%	0.0%	0.0%	57.7%	0.0%	14.6%	0.0%	0%	0.0%	0.0%	0.0%	0.0%
	Condensation	Non efficace	0.0%	0.0%	13.9%	13.9%	0.0%	0.0%	0.0%	0.0%	28.8%	28.8%	7.3%	7.3%	0.0%	0.0%	0%	0.0%	0.0%	0.0%
		Efficace	0.0%	0.0%	0.0%	27.7%	0.0%	0.0%	0.0%	0.0%	0.0%	57.7%	0.0%	14.6%	0.0%	0.0%	0.0%	0%	0.0%	0.0%
Autres		Non efficace	0.0%	0.0%	7.2%	7.2%	4.5%	4.5%	11.2%	11.2%	15.1%	15.1%	3.8%	3.8%	0.0%	0.0%	0.0%	0.0%	24%	23.9%
		Efficace	0.0%	0.0%	0.0%	14.5%	0.0%	9.0%	0.0%	22.4%	0.0%	30.2%	0.0%	7.6%	0.0%	0.0%	0.0%	0.0%	0.0%	48%

An example, showing the interpretation of the matrix: the line, which is underlined, is representing the category corresponding to “Fuel-low temperature-inefficient” and the new repartition, in term of percentage of house numbers, on the instant t+Δt, is also shown, that is: 13.9% electricity thermodynamics, 28.8% wood pellets, 7.3% wood stove.

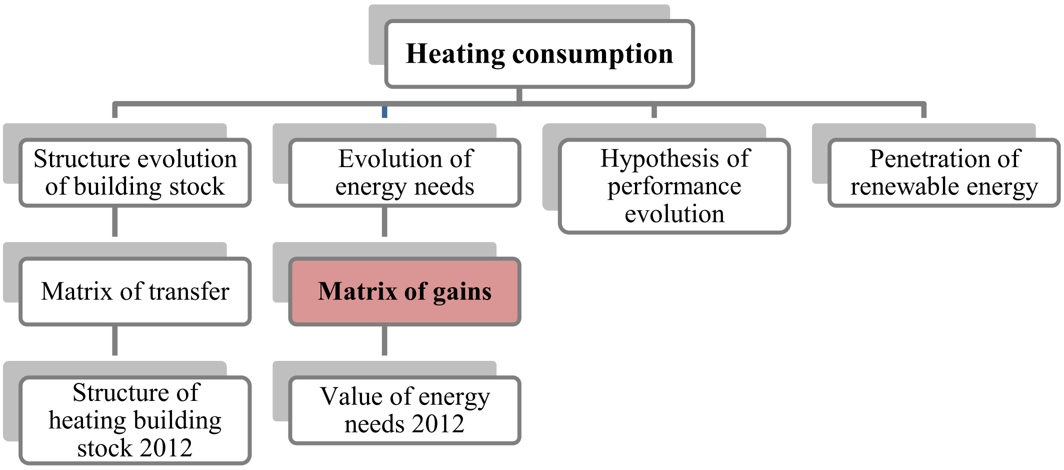
The 0% value, on the diagonal, indicates that the solution Fuel-low temperature-inefficient is no longer used at time t+Δt.

4.2. The matrix of gains

The second matrix characterizing the model is that of gains in energy needs: this matrix translates in terms of percentage the change of energy efficiency class for buildings, due to renovation works and variations of internal temperatures in buildings.

The graph reported shows schematically the basis for the consumption calculation according to the heating systems, and the location of the analyzed matrix within the chain of calculus.

Figure 5.5 : Schema of the consumption calculus for heating systems



The following Table represents the percentage of gains based on the change of energy efficiency class, between the various situations in 2012 and 2050[91].

The calculus of this matrix is based on two steps. The first one indicates the estimate in term of percentage of gains due to renovation, that means a change of the energy efficiency class. The second one is indicating the estimate of gains due to an interior temperature variation.

Of course, the change of the energy efficiency class has an influence on the energy needs. These changes are translated into percentage. Such gains are depending on the initial and

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[91] Hypotheses elaborated by the EDF expert, based on data of unit consumption of CEREN and the thermal regulations.

energy class (in this study, the level of isolation). The following table reports the gains for all possible energy class evolutions, and for different category of building stock.

Table 5.10 : Percentage of gains depending on isolation level for buildings in 2010, as well as isolation level in 2050, hypothesis EDF R&D

	SFD				**MFD**			
	Before1950	1950-1974	1975-1999	After2000	Before1950	1950-1974	1975-1999	After2000
Situation 2010	*Pas isolé*	*Pas isolé*	*Isolation*	*Isolation +*	*Pas isolé*	*Pas isolé*	*Isolation*	*Isolation +*
Pas isolé	0%	0%			0%	0%		
Isolation	30%	30%	0%		30%	30%	0%	
Isolation +	50%	50%	30%	0%	50%	50%	30%	0%
BBC	80%	80%	50%	30%	80%	80%	50%	30%
Passif	90%	90%	70%	50%	90%	90%	70%	50%

The buildings built before 1975 have been classified as “Non insulated”. According to 1974 thermal regulations, the buildings were built with the aim of achieving more reasonable consumptions, and had therefore a higher insulation level. Buildings constructed between 1975 and 2000 are considered “Insulated” and buildings constructed between 2000 and 2012 as “Insulated +”.

The second aspect considered for evaluating the matrix of gains is the variation of interior temperature. This aspect is analyzed in a simplified manner to reflect the behavior of the inhabitants[92]. For each variation, defined as the difference between the average value of temperature at the initial state, a percentage has been assigned: a decrease of 1°C of temperature may results in a decrease of energy consumption varying between 6 and 10%, depending on the level of performance of the buildings[93].

These percentages of gain are added to the gains obtained by the building renovations. The matrix of gains is obtained by adding the two contributes to the reduction of energy needs: the energy efficiency class and the interior temperature.

$$\text{Matrix of gains} = \text{f}\left(\text{Level of insulation, } \Delta\left(\text{Internal temperature}\right)\right) \tag{4}$$

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[92] The inhabitants behaviors are complicated to model, it needs to simulated social, perception, cognitive and psychological elements to generate inhabitants’ behaviour over time. A paper that explain how inhabitants' behaviour is a significant factor that influences energy consumption is, “Agent Based Framework To Simulate Inhabitants’ Behaviour In Domestic Settings For Energy Management”, Ayesha Kashif , Julie Dugdale, Stéphane Ploix.

[93] Hypotheses elaborated by the EDF expert and not available to public.

4.3. Calculus of consumptions

The final housing stock energy consumption, on the instant t, is the sum of consumptions of all types of buildings (single and multyfamily dwellings), of all periods of construction, and of all uses.

$$Consu.RES\left(t\right)=\sum_{i=1}^{5}\sum_{j}\sum_{k}Consu.RES\left(t\right)_{i,j,k} \tag{5}$$

i = period of construction [Before 1949, 1950-1974, 1975-1999, 2000-2012, New]
j = type of building [Single family dwelling, Multy family dwelling]
k = uses [Heating, Hot Water, Cooking, Cooling, Electricity Specific]

The calculus of final energy consumptions for each uses has been obtained by different methodologies, based on the data-set available and the characteristics of each system. In the following section the detailed methodologies are reported.

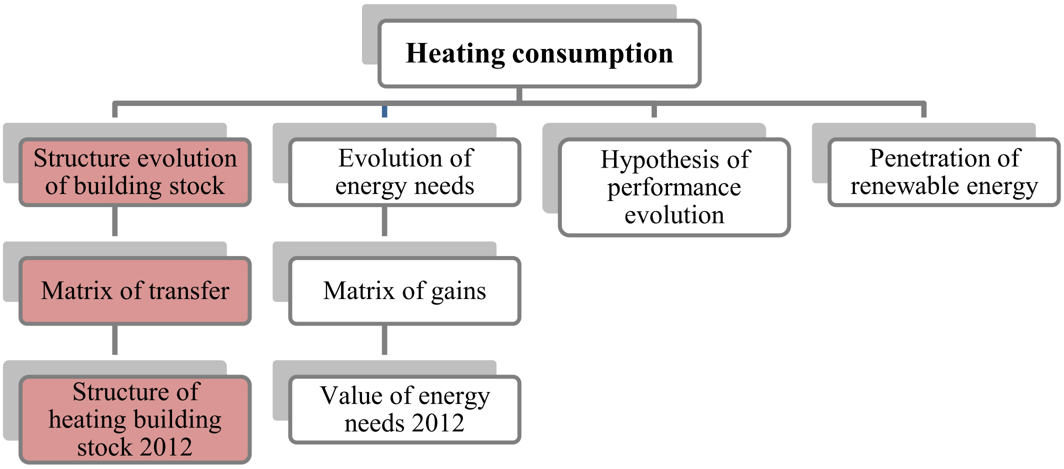
4.3.1. System of heating

Heating is representing the major consumption use. The final energy consumption for each energy is the sum of product between the unit consumptions and the number of lodgment for the analyzed category.

$$\mathrm{Consu\ RES}(\mathrm{t})_{\mathrm{i,j,heat}}^{\mathrm{Elec}} = \mathrm{CU}(\mathrm{t})_{\mathrm{heat}_{\mathrm{PAC}}}^{\mathrm{Elec}} \times \mathrm{Nblg}(\mathrm{t})_{\mathrm{heat}_{\mathrm{PAC}}}^{\mathrm{Elec}} + \mathrm{CU}(\mathrm{t})_{\mathrm{heat}_{\mathrm{Joule}}}^{\mathrm{Elec}} \times \mathrm{Nblg}(\mathrm{t})_{\mathrm{heat}_{\mathrm{Joule}}}^{\mathrm{Elec}} \tag{6}$$

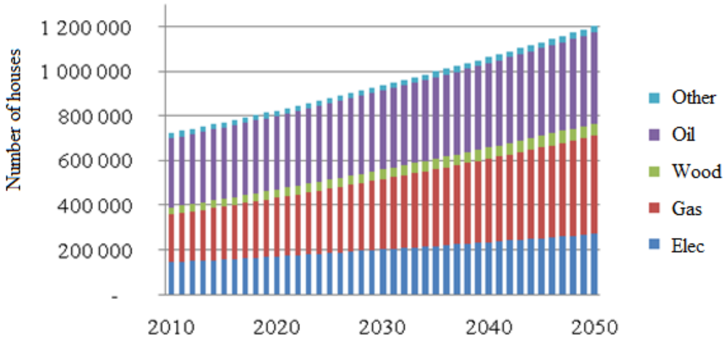
For the calculus, the first step taken was the estimation of the structure changes for the housing stock (number of houses) on the instant t+Δt: for this aim, the matrix of transfer, previously analyzed, has been created.

Figure 5.6 : First step taken for a methodological schema for the calculus of heating final energy consumptions.



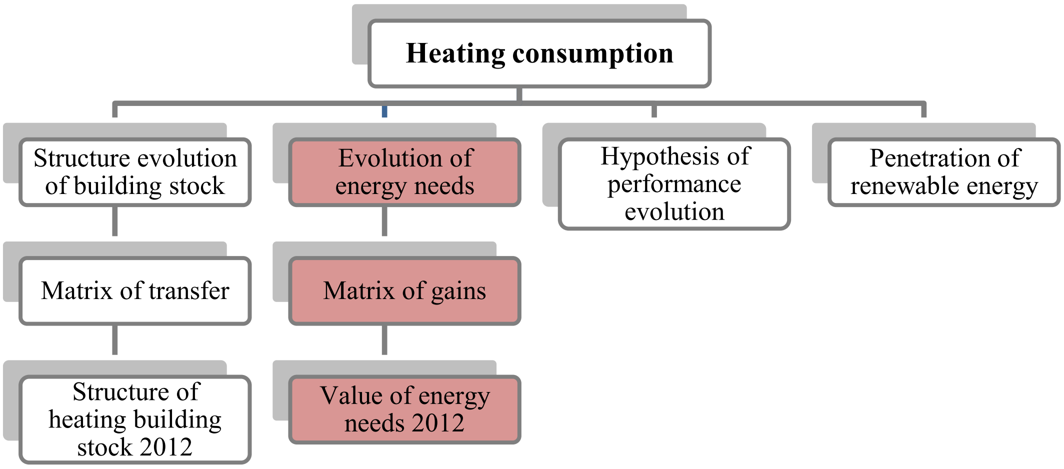
The initial structure for heating building stock, divided according to energy and technology, is multiplied by the matrix of transfer: the new structure of stock on the instant t+Δt is so obtained; the trend between t and t+Δt is estimated trough a linear interpolation.

Figure 5.7 : Structure trend for residential building stock, according to number of houses by energy for the single family dwelling within the « Baseline » scenario



Then, the calculus for the evolution of final energy needs has been obtained through the matrix product between the values of needs on the instant t (calculated as shown in the previous section) and the matrix of gains.

Figure 5.8 : Second step of methodological schema for the calculus of final energy consumptions for heating



Finally, the total volume of end energy consumption is estimated in function of: new building stock structures; evolutions of needs (t, t+Δt), evolution rate for the system performances, as well as the penetration of renewable energy. The consumption trend between the instant t and t+Δt is hypnotized as linear.

4.3.2. System of Domestic Hot Water

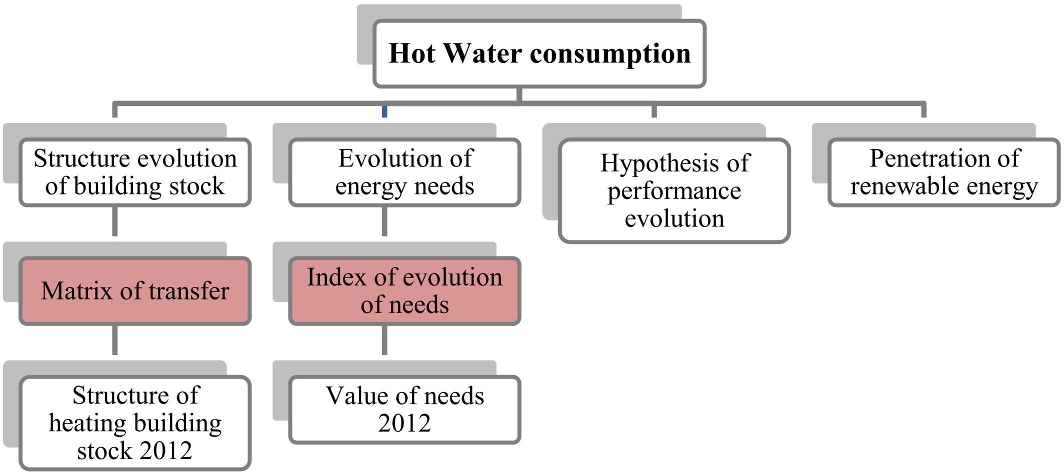
The hot water system has been treated with the same main principles than heating. The main differences are:

- the evolution of final energy needs has been analyzed in a more simply way, according to an evolution index for needs, estimated by CSTB (and explained in the previous section);
- the matrix of transfer is the product of two matrices, that is the matrix of energy changes and technology. The isolation of buildings has no influence on the hot water system. The following Table represents a transfer matrix example for the analyzed system.

Table 5.11: Matrix of transfer for the hot water system in single houses, for « Baseline » scenario, based on the EDF R&D hypotheses.

		Electicity		**Gas**		**Fuel**		**Other**
		Joule	*Thermo*	*Standard*	*Condensation*	*LT*	*Condensation*	*(Solair)*
Électricity	*Joule*	100%	0%	0%	0%	0%	0%	0%
	Thermo	0%	100%	0%	0%	0%	0%	0%
Gas	*Standard*	0%	0%	99%	0%	0%	0%	0%
	Condensation	0%	0%	0%	99%	0%	0%	0%
Fuel	*LT*	1%	1%	0%	0%	98%	0%	0%
	Condensation	1%	1%	0%	0%	0%	98%	0%
Other	*(Solair)*	50%	50%	0%	0%	0%	0%	0%

Figure 5.9 : Methodological schema for the calculus of final energy consumptions for hot water system



4.3.3. Cooling, Cooking, Electricity Specific

The cooling, cooking and electricity specific systems represent a minimum part of the total final energy consumption of the region; therefore, they are considered in a simplified way. Cooking and Cooling represent 5% of the final energy consumption in Alsace, while the Specific electricity 14%.

The methodology consists in the calculus for the household consumption evolution based on the equipment parameters and on the consumption for equipped household (MWh), depending on the climate in the area analyzed.

Concerning cooling, the consumptions are estimated by the hypotheses on equipment rate, consumption for equipped household and the evolution index of the system performances. The equipment rate and consumption for equipped household depend on the climate existing in the zone of interest (H1, H2, H3).

$$\text{Consumption}_{\text{cooling}} = \text{Consumption}_{\text{equipped household}} * \text{equipment rate} * \text{index of evolution of performances of systems} \quad (7)$$

The fuel and electricity consumptions for cooking system have been estimated according to the hypotheses for the equipment rate, the consumption for equipped household and with an evolution index for equipment rate. The equipment rate and the consumption for equipped household depend on the climate zone of interest (H1, H2, H3).

$$\text{Consumption}_{\text{cooking fuel}} = \text{Consumption}_{\text{equipped household fuel}} * \text{equipment rate}_{\text{fuel}} * \text{index of evolution of equipment rate}_{\text{fuel}} \quad (8)$$

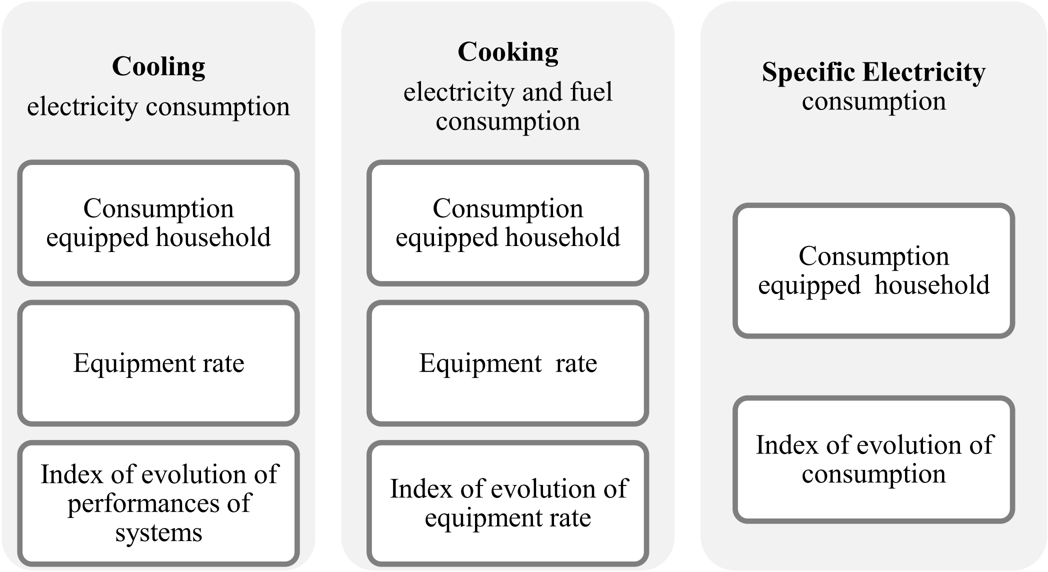
$$\text{Consumption}_{\text{cooking elec}} = \text{Consumption}_{\text{equipped household elec}} * \text{equipment rate}_{\text{elec}} * \text{index of evolution of equipment rate}_{\text{elec}} \quad (9)$$

Finally, the consumptions for specific electricity are calculated through the consumptions for equipped household with a consumption evolution index for specific electricity. These values depend on the climate zone of interest (H1, H2, H3).

$$\text{Consumption}_{\text{electricity specific}} = \text{Consumption}_{\text{equipped household}} * \text{index of evolution of consumption}_{\text{electricity specific}} \quad (10)$$

The following graph shows a synthesis of the three simplified methodologies.

Figure 5.10 : Schema of the simplified calculus for the final energy consumption concerning cooling, cooking and specific electricity systems.



4.4. Production of decentralized energy: renewable energies

The renewable energies considered in this study are photovoltaic, micro-wind and solar thermal. These energies are considered as exogenous parameters; the product energies are auto consumed within the same lodgment[94].

The photovoltaic and the micro-wind have an influence on the heating system with lower consumptions and emissions. The number of houses interested in renewable energies is calculated according to the penetration percentage of these factors, afterwards the share of avoided energy and CO_2 related, are calculated.

The energy product through renewable energies is estimated according to the climatic area in analysis, the penetration rate of photovoltaic and the micro wind within the residential building stock, as well as the installed power from technologies.

This energy is then subtracted from the total final energy consumptions. The CO_2 emissions, avoided thanks to the renewable energy production, is estimated according to the renewable energy production and the CO_2 content coefficient for kWh final energy.

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[94] Distributed generation or decentralized energy generates electricity from many small energy sources. Most countries generate electricity in large centralized facilities, such as fossil fuel (coal, gas powered), nuclear, large solar power plants or hydropower plants. These plants have excellent economies of scale, but usually transmit electricity long distances and negatively affect the environment. Distributed generation allows collection of energy from many sources and may give lower environmental impacts and improved security of supply.

In the following Figure the photovoltaic and micro wind production values for each climate area are shown.

Table 5.12 : Photovoltaic production values for 1 kWc (MWh). 1 kWc (MWh) for each climatic zones depending on solar strength.

PV Production for 1 kWc (MWh)

Zone	
H1	0.95
H2	1.1
H3	1.3

Source: Rt-batiment

Table 5.13 : Micro wind Production values for 1 kWc (MWh) 1 kWc (MWh) for each climatic zones depending on wind patterns.

Micro wind production for 1kWc (Mwh)

Zone		*m/s*
Zone1	*0.1*	*<3,5*
Zone2	*0.15*	*3,5 - 4,5*
Zone3	*0.2*	*4,5 - 5,0*
Zone4	*0.25*	*5,0 - 6,0*
Zone5	*0.4*	*>6,0*

Source: ADAME 2009

The solar thermal is an exogenous factor influencing the consumptions of hot water. It is represented par "Other" within the energy classification.

6.
RESULTS AND SENSITIVITY ANALYSIS

As mentioned in the above chapter, the simulator allows the calculus of certain macro indicators, that is: environmental, economic and social indicators at regional scale. Moreover, it is possible to carry out sensitivity analysis on the results, based on the main parameter changes.

Such indicators have been chosen thanks to propositions and negotiations carried out with the local authorities, so as to underline the main energy issues and to allow to raise public awareness.

This section shows the main results of the scenarios created in this study, together with a comparison between the different available choices; moreover, a sensitivity analysis has been developed showing the most sensitive parameters for the actions considered.

The indicators suggested in this study are:

- the total volume of final energy consumptions and the unitary values per household (kWh, kWh/hh);
- the total volume of CO_2 emissions and the unitary values per household (t eqCO_2, t eq CO_2/hh);
- the volume of investments for the renovation of buildings and for the changes of technologies (M€);
- the increase of employees within the building sector (WFT[95]);
- the energy bill for household (k€).

For the analysis, two important assumptions have been considered:

- first, the economic indicators have been considered at an yearly basic price,

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[95] Work full time

- second, the results obtained from the residential building stock are comprehensive of an increase of about 60% stock, by the year 2050.

The calculus of final energy has been carried out based on the number of houses for each type of energy, on the horizon 2050. The different steps taken for the calculus have been shown in the previous chapters: the evolution of consumptions is depending on the evolution of needs.

The CO_2 emissions have been estimated based on the kg CO_2/kWh for each energy and each use; making use of a transformation coefficient, the kg eq Carbone/kWh has been calculated. Moreover, the renewable energy production is considered as CO_2 emissions being avoided.

The global calculus for the estimation of CO_2 emissions is as follows:

$$E_{s,a,t} = A_{a,t} \times F_{s,a} \tag{11}$$

$E_{s,a,t}$ = Emission of substance “s” and activity “a” in the time “t”

$A_{a,t}$ = Quantity of activity of activity “a” in the time “t”

$F_{s,a}$ = factor of emission of substance “s” and activity “a”.

The emission factor is based on the final energy consumptions within the building stock.

Table 6.1: Coefficient values used for the calculation of CO_2 emissions within the residential building stock. The transformation coefficient CO_2/Carbon used is 0.273.

Energy		kg CO2/kWh	kg eqCarbon/kWh
Electricity			
	Heating	0.18	0.049
	Hot Water	0.04	0.011
	Cooking, Electricity specific	0.06	0.016
	Cooling	0.1	0.011
	Photovoltaic	0.06	0.016
Gas		0.234	0.064
Fuel		0.3	0.082
Biomass	*SH*	0.013	0.004
	FH	0.176	0.048

Source: ADEME and EDF 2004

The volume of investments for the renovation of buildings and the changes of technologies have been estimated based on the type of renovation per lodgment and the kind of technology chosen. All the values for investments are based on real statistical values for the works already done within the region.

The increase in employees for the building sector has been calculated based on data from ADAME[96] and OREF[97]. These studies have evaluated the employments per M€ of investments placed for renovation and changes of technology.

The household energy bill is based on the data from the *« Ministère de l'Ecologie, du Développement durable, des Transports et du Logement* » and from the *« Service de l'observation et des statistiques* (SOeS) ».

1. The results

The macro analysis of the main indicators for the four scenarios is a direct and immediate communication tool. The following Table shows, for each scenario, the variation of consumption and emission volumes, between 2010 and 2050, the gain in unitary consumptions and emissions, the share of renewable energy introduced and, finally, the economic indicators (investments, employment and household bill).

Table 6.2: Synthesis of the main aggregated indicators for the four analyzed scenarios

	Baseline	*No fuel*	*Renewable energy*	*Factor4*
Variation of consumptions	24%	12%	-1%	-24%
Variation of emissions	20%	-25%	-41%	-61%
Gain of consumptions (% per hh)	-18%	-26%	-34%	-50%
Gain of CO_2 (% per hh)	-20%	-50%	-60%	-74%
Part of renewable energy %	8%	23%	47%	38%
Investment in the old (M€)	4 374	6 583	16 360	28 952
Employment (ETP)	45 704	68 599	173 094	403 981

The results are the aggregations of the results of each category analyzed into the study. The aim to this aggregation is to show the main tendency of the whole residential building stock.

As a first analysis, the following Figure is showing the volume variation for consumptions and emissions. Between 2010 and 2050, an increase in final energy consumption of more than 10% for the scenarios "Baseline" and "No Fuel" is appearing, these results are due to the low renovation in buildings and to the low increase in performing technologies. There is a variation of about 0% of the energy consumption volume in the "Renewable energy" scenario; the renewable energy increase, which permits an energy consumption reduction, compensates the volume increase of building

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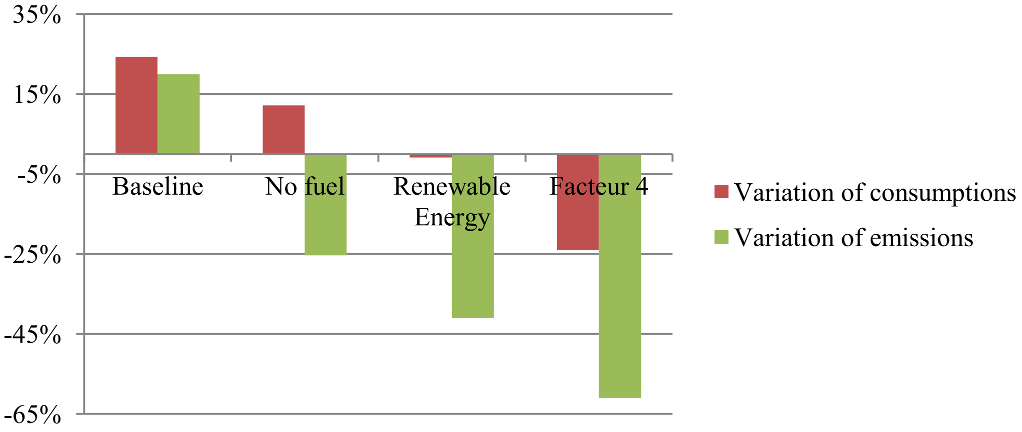
[96] ADEME, Marches, emplois et enjeu énergétique des activités liées a l'amélioration de l'efficacité énergétique et aux énergies renouvelables: situation 2008-2009 – perspectives 2010, October 2010.

[97] OREF, observatoire régional emploi formation, Alsace, Febrary 2012

stock. The high reduction shown in “Factor 4” scenario is due to the renewable energy increase and to a high rate building renovation.

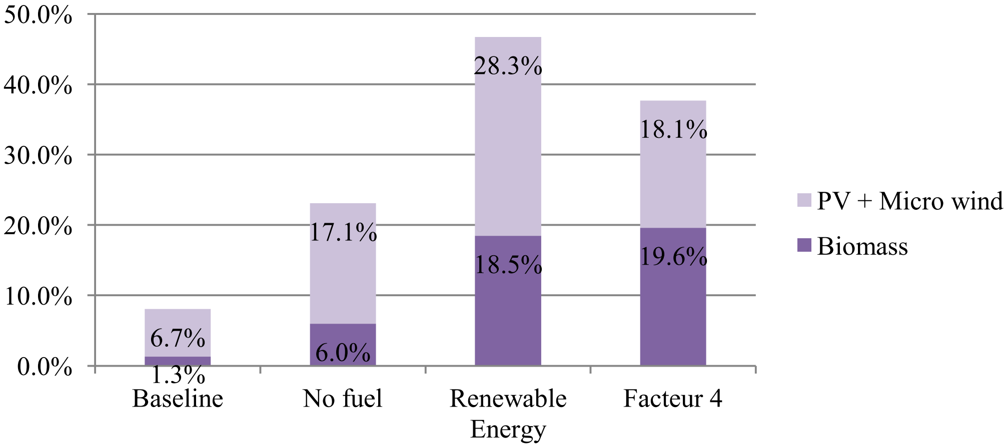
The CO_2 emission volume shows a 20% increase for the “Baseline” scenario, while the “No Fuel” scenario, is showing a 25% reduction, this is due to the energy change, that is a suppression of the fuel energy, which is the energy having the highest carbon content level. The “Renewable energy” and the “Factor 4” scenarios show a massive reduction in CO_2 emission volume, due both to the reduction in total energy consumptions and to the switch to a lower carbon content energy.

Figure 6.1: Total volume variation for final energy consumptions and CO_2 emissions.



Details concerning the final energy consumptions produced by renewable energy, and the share of wood resources used, are showing in the following Figure.

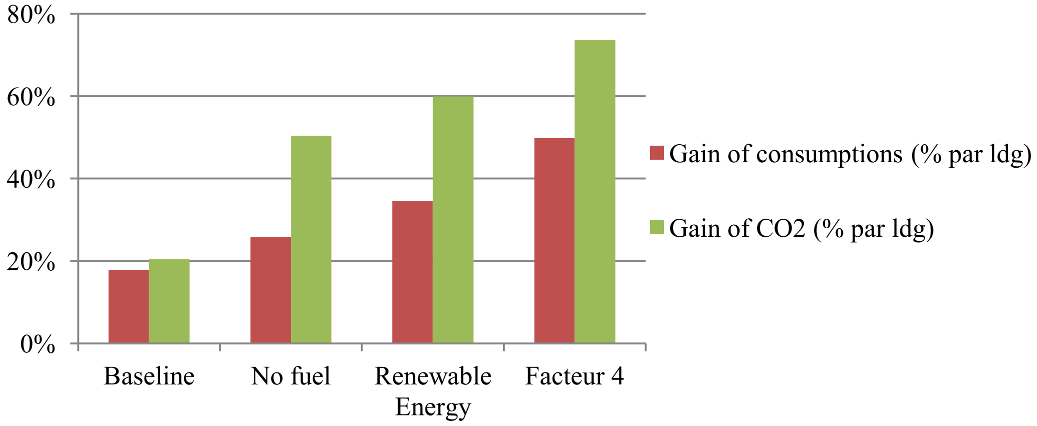
Figure 6.2 : % of renewable energies over the total final energy consumption by 2050, referred to the scenarios analyzed.



Secondly the analysis of gain of unitary final energy consumption and emissions shows that there is a gain for the four scenarios, due to the respect of the new thermic regulation into the new building stock and due to renovation on the old one. The different gains are due to the different rates of renovation, and to the different energy and technology solutions adopted. The gain of unitary consumptions has a range for the scenario "Baseline" and "Factor 4" between 18 and 50%. It is important to underline that also with the scenario "Baseline" it is possible to reduce the consumption per houses, the problem is that is not enough to compensate the increase of the number of lodgments estimated to 2050 and the consequent increase of total volume of consumption.

In terms of gain of CO_2 emissions the results of the four scenarios have a similar tendency to that of the gains of consumptions. The most remarkable aspect is that to join the target of reduction of 75% of CO_2 emissions by 2050[98] all the actions of renovations, change of energies and technologies implemented into the scenario "Factor 4" are indispensable.

Figure 6.3: % for gains regarding unitary final energy consumptions and CO_2 emissions, between 2010 and 2050.



The socioeconomic indicator analysis points out that the "Baseline" and "No Fuel" scenarios are the most accessible ones, with no heavy investments, on the contrary, for implementing the "Renewable Energy" scenario and especially the "Factor 4" one, important and increasing investments are needed, due to the buildings renovation and to the choice of more performing technology. The employment increase is depending on the investments; the "No Fuel" and "Renewable Energy" scenarios though, are showing more favorable ratios between investments and employment than the "Factor 4" scenario.

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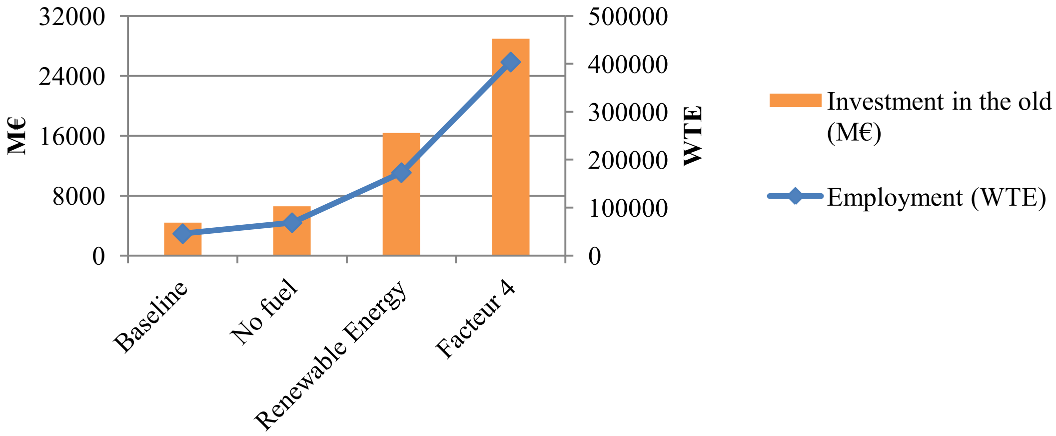
[98] Energy Roadmaps 2050, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions.

Figure 6.4: Investments in the old building stock to year 2050, and employment increases due to such investments.



The following Table is showing the ratio between each analyzed scenarios and the "Baseline" one. It is remarkable to notice that the "Factor 4" scenario is 6.6 times more expensive than the "Baseline" one, it is allowing, though, to cut down the household bill more than a half . On the basis of the socioeconomic indicators, the "No Fuel" scenario is resulting the most rentable one, as a matter of fact, it shows an investment 1.51 times higher than the "Baseline" scenario but it allows to have a reduction in the household bill of 20%.

Table 6.3: Ratio between the "Baseline" scenario and the other three scenarios for the socio-economic indicators.

Ratio compared to Tendanciel	*Baseline*	*No fuel*	*Renewable Energy*	*Facteur 4*
Investment in the old (M€)	1	1.51	3.74	6.62
Employment (ETP)	1	1.50	3.79	8.84
Energy bill (k€)	1	0.81	0.66	0.55

After this quantitative analyses, the main qualitative points of each scenarios are briefly resumed:

Scenario "Baseline"

- Exigent thermal regulation within the new building stock
- Increase in final energy consumptions and CO_2 emissions
- Low renovation within old building stock
- Low investments and local employment

Scenario "No Fuel "

- Important reduction in CO_2 emissions

- Accessible investments
- Integral renovation of heating systems
- Over use of the available wood resource
- Low attention to the insulation in buildings

Scenario " Renewable energy"

- Increase in use of renewable energies
- Integral compensation of all consumptions for the building stock
- Creation of local employment
- Import of biomass, and atmospheric pollution
- Investments, difficult to access

Scenario "Factor 4"

- Total volume reduction of final energy consumption for all building stock
- 75% reduction in CO_2 emissions per house
- 50% reduction in unitary final energy consumption
- Not rentable investments for the sector
- Unfavorable ratio between creation of employment and investments.

1.1. Details of scenario "No fuel"

All the calculations have been made for the different uses and for the different energies and technologies. The "No fuel" scenario has been considered as a feasible one, also for the horizon time 2030, able to achieve a durable regional development.

The following section shows the results regarding the "No Fuel" scenario: firstly, the evolution of the building stock division, based on the used energies; it shows an increase in the house number, elimination of houses using fuel energy, and an increase in other energies, especially electricity and gas.

Secondly, the results concerning the evolutions for final energy consumptions, subdivided by energies and uses, are reported. Heating is the main use, specific electricity and hot water are following.

Finally, the evolutions of CO_2 emissions are reported; it is evident, that by eliminating energy fuel, significant reductions in CO_2 emissions are obtained.

Figure 6.5 : Structure evolution for building stock, subdivided according to the energy used, referred to « No Fuel » scenario.

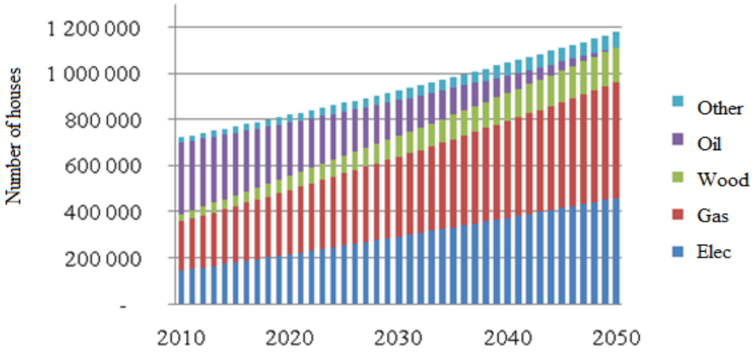


Figure 6.6: Evolution of final energy consumption, subdivided according to the energy used, referred to « No Fuel » scenario.

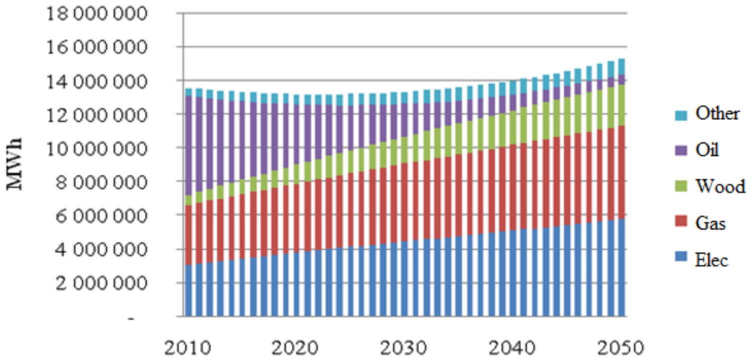


Figure 6.7 : Evolution of final energy consumption subdivided according to the uses, referred to « No Fuel » scenario.

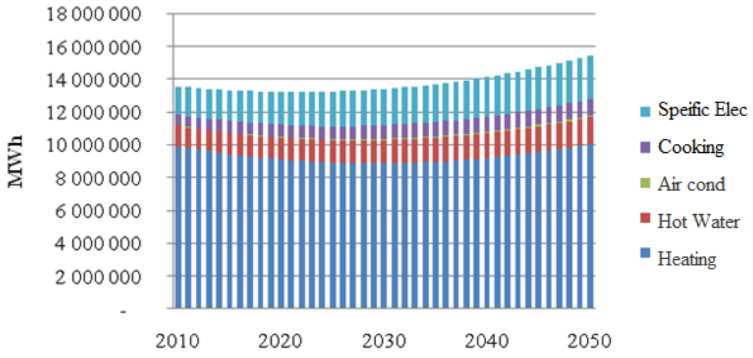


Figure 6.8: Evolution of CO_2 emissions subdivided according to the energy used, referred to « No Fuel » scenario.

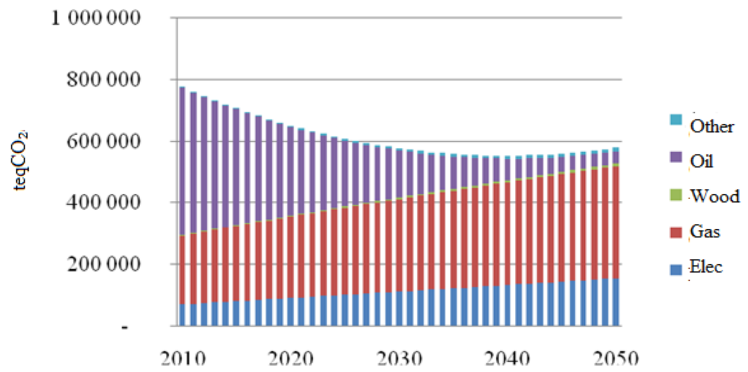
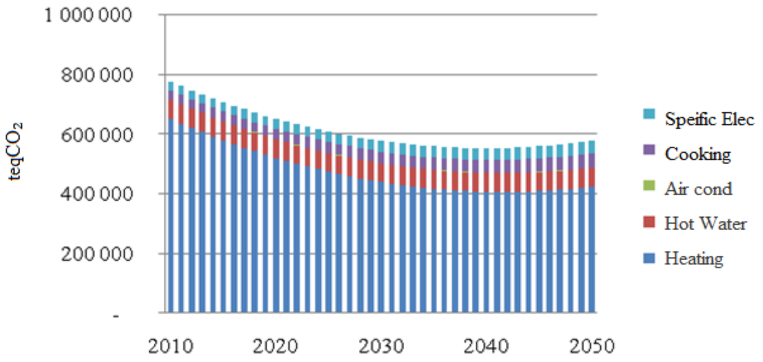


Figure 6.9 : Evolution of CO_2 emissions subdivided according to uses, referred to « No Fuel » scenario.



2. Sensitivity analysis

The sensitivity analysis is the study of how the uncertainty in the output of a mathematical model or system can be attributed to the different sources of uncertainty in its input. According to the aim of this study, this analysis is useful so as to increase a better understanding of the relationships between the input and the output variables, to enhance communication from modelers to decision makers, to find rank of values of input factors for which the model output is either maximum or minimum.

The sensitivity analysis is made based on the hypotheses of the “Baseline” scenario. The key variables are modified in a range of values, in order to evaluate the variation of the results. The objective aims at studying how and in which proportion the modification of the different variable hypotheses in input can influence the final results. This analysis is based on the change of a family concerning the input values and the invariance of the other.

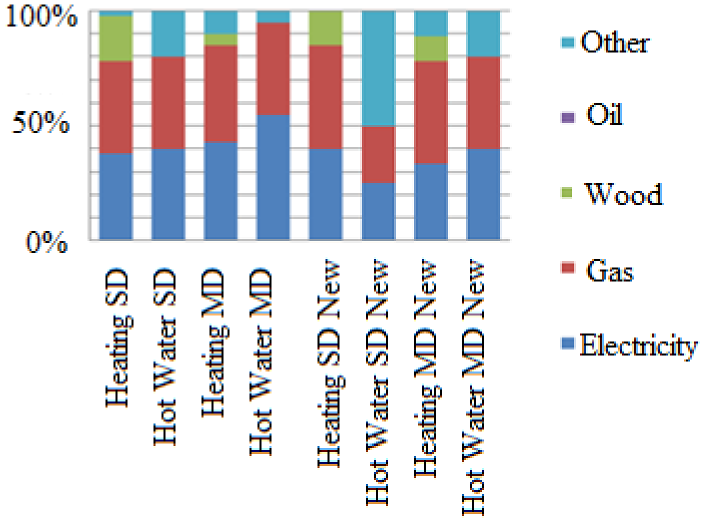
This sensitivity analysis has taken into consideration three scenarios: one renovation scenario for half of the building stock, one scenario where a wide use of renewable energy is considered, especially with reference to photovoltaic and micro wind, and another scenario with no use of the fuel energy.

"*Old building stock BBC*": 45% of old building stock reaches a BBC isolation level.

"*Photovoltaic + Micro wind*": half of the old and new family houses and 33% of the Multyfamily houses are equipped with photovoltaic. The micro wind shows in average a 15% penetration rate.

"*No Fuel*": the share of fuel energy is eliminated and replaced by electricity, gas and wood. The following Figure shows the new energy subdivision for residential building stock. With respect to the baseline scenario, the technologies remain the same.

Figure 6.10 : New energy subdivision for residential building stock witt reference to "Baseline-no fuel" scenario.



By applying the Energy Efficiency simulator, the calculus with the new scenario has been made. The main aggregated results obtained for the "Baseline" scenario and the three alternatives are reported in the following Table.

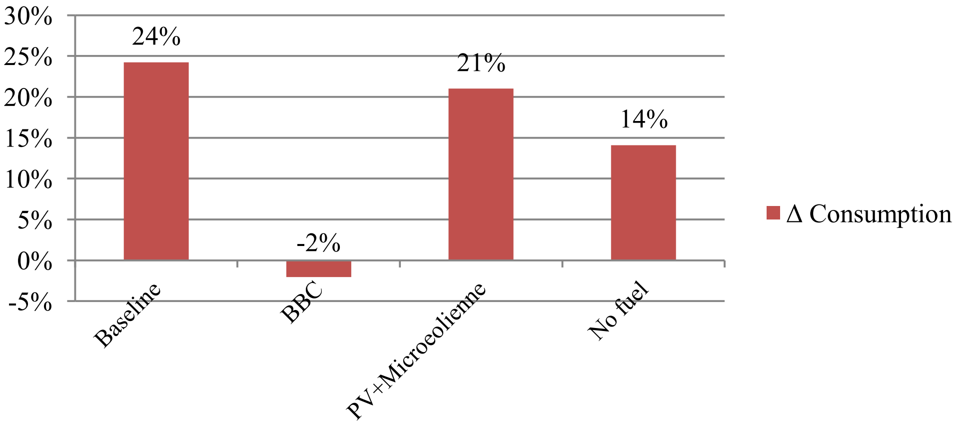
Table 6.4 : Synthesis of the main aggregated indicators for the four analyzed scenarios

	Baseline	*Old building stock BBC*	*PV+Micro wind*	*No fuel*
Variation of consumption	24%	-2%	21%	14%
Variation of emissions	20%	-11%	19%	-25%
Gain of consumption(% per hh)	-18%	-35%	-18%	-25%
Gain CO_2 (%per hh)	-20%	-41%	-22%	-50%
Part EnR %	8%	9%	14%	22%
Investments old ME	4 374	13 091	9 110	5 796
Employment WTE	45 704	185 182	78 860	58 919
Bill energetic (€*10^5)	14 213	11 379	14 213	11 708

The analysis of the results is showing that the main variations result to be in the "Old building stock BBC" scenario and in "No Fuel" scenario. On the other hand, these scenarios are the less feasible for investments.

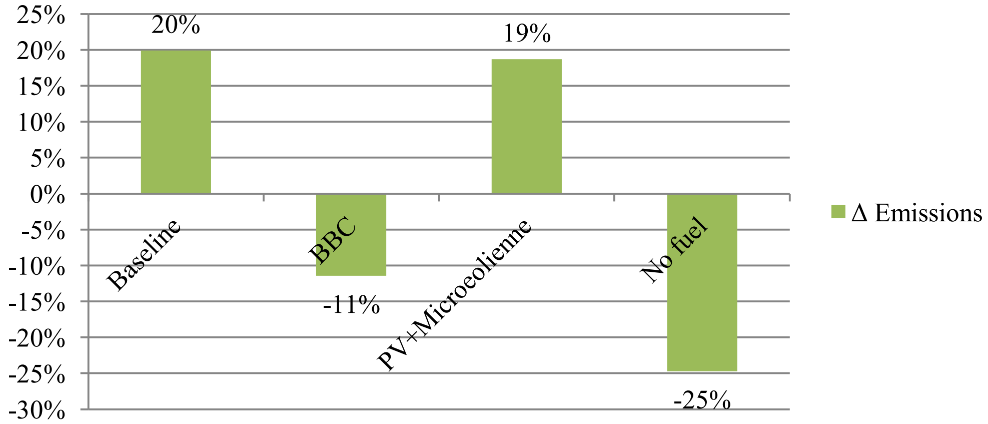
In the first analysis, the focus is more on the final energy consumptions for the three alternatives to the baseline; the only alternative that enables a change of tendency and a total volume reduction for final energy consumptions is the "Old Building stock BBC" scenario, the others are showing a low difference compared to the baseline.

Figure 6.11 : Total volume variation for final Energy consumptions between 2010 and 2050 for the Baseline scenario and the three alternative scenarios.



Secondly, the analysis concerning CO_2 emissions is showing that the alternative, which is allowing a drastic change from the baseline scenario, is the "No Fuel", followed by the "Old building stock BBC". A suppression of fuel energy from the "Baseline" scenario enables a total volume reduction in CO_2 emissions of about 25%.

Figure 6.12 : Total volume variation of CO_2 emissions between 2010 and 2050 concerning the "Baseline" scenario and the three alternative scenarios.

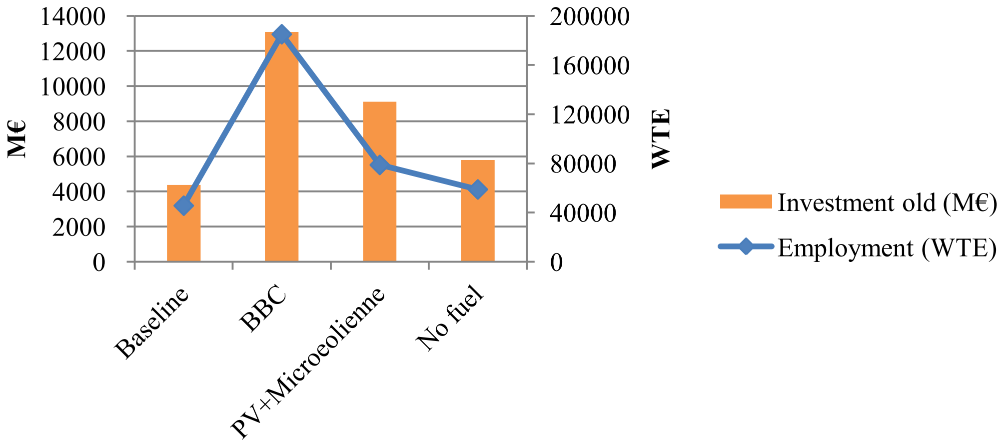


These first two analyses shows that the most significant action to obtain a high total volume reduction for final energy efficiency is the building isolation (which would allow an energy efficiency); to the other hand, the most significant action to obtain reductions on CO_2 emissions is the suppression of the fuel energy.

Moreover, the analyisis for socioeconomic indicators is showing that the “Photovoltaic + Micro wind” scenario is an expensive one in terms of investments, and has a high influence on the employments, but it is not very sensible for what consumption and emission gains are concerned.

Important to remark is, that the renewable energy (photovoltaic and micro wind) are not yet technologies that alone can solve the problems of energy efficiency, but they have to be integrated within the range of the possible actions to be implemented.

Figure 6.13 : Investments in the old building stock to 2050, and the increase in employment is lying in these investments.



The sensitivity analysis shows how a parameter variation can change the results. In this study, to a didactic aim, the values of the parameters have been analysed considering a wide variation of values, of course, within the limit of a possible value range.

7.
CONCLUSION

This study has been aimed at, on one hand, the comprehension of the possible feature evolutions for residential building stock on a regional scale and, on the other hand, to feature out the public awareness on subjects concerning energy efficiency and fuel poverty.

The specific object of the study is to build a tool able of helping to take decisions concerning future territorial issues. For this reason, an energy simulator, at the horizon time 2030-2050, and on a regional scale has been developed. The analyses carried out are based on different scenarios for actions to be taken relating to renovations of buildings stock, developments of renewable energy, changes of energies, as well as renovations of technologies. These different scenarios have allowed different types of results (environmental, economic, social…), including their comparison.

To achieve the "Factor 4" scenario[99], so as wished by the European and national politics, a wide range of different actions, in comparison to the "Baseline " scenario, has been to be implemented. This scenario has been achieved by developing renewable energies, interventions on renovations, changes of used energy, as well as technological renovation. In order to achieve the global results wished, one single action is not sufficient. As a matter of fact, for the reduction of energy consumptions, a politic with strong and diffuse actions on the renovations of buildings is desirable, unfortunately, this is economically unrealizable.

The study is focusing on a sensitivity analysis of the different alternative scenarios, for what the "Baseline" scenario is concerned, in order to underline and show the most sensible parameters to this research. The influence the different parameters have on the indicators considered has been pointed out. The building insulation is the parameter having the main influence on the reduction in energy consumptions, while the suppression of energy fuel has the main influence on the reduction in CO_2 emissions.

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[99] The Factor 4 project follows the Sustainable Development World Strategy, the Kyoto protocol and the European energy policy which is to reduce by a factor 4 energy consumption in European countries before 2050.

By studying the various scenarios of actions, an evaluation of the different possible strategies has been possible. The results obtained are, sometimes, economically or socially unrealizable. Even though, the results obtained from the study may give some elements of knowledge and reflection for regional authority and collectivities, so as to improve energy systems in the future.

1. The perspectives

In order to become a possible and veritable regional tool for energy transition, the presented study should be widen a regional territorial and technical perimeter.

The perspectives for development could be:

- Extension to other regions and other local collectivities;
- Widening of technical perimeter: residential sector, tertiary, transports;
- Analysis of energy demands, supplies and networks;
- Study of possible energy price evolution.

8.
APPENDIX

LIST OF FIGURES

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A. APPENDIX FUEL POVERTY

There is no universal understanding of the issue. General poverty can be defined as living with the uncertainty of being able to maintain or recover a secure financial status. The concept of fuel poverty, however, has not yet been clearly defined within the countries taking part in the study with the exception of the United Kingdom. The United Kingdom is the only country to have come up with an official definition: “a household is in a situation of fuel poverty when it has to spend more than 10% of its income on all domestic fuel use, including appliances, to heat the home to a level sufficient for health and comfort.” (D. Chérel, April 2009)

However, given differences in climate, methods of heating, and assessment of income, this definition is not readily applicable to other countries. Therefore, the EPEE[100] consortium proposes a less precise definition of fuel poverty – in effect where a household finds it difficult or impossible to ensure adequate heating in the dwelling at an affordable price.

Each country may then adapt this definition to reflect national characteristics and criteria, while retaining a common view of the problem. The first study carried out by EPEE focuses on the causes and consequences of fuel poverty, with particular reference to vulnerable households.

It affects mainly vulnerable households: fuel poverty affects a wide range of families and individuals. However, households most susceptible to fuel poverty combine low income with an additional degree of vulnerability such as the elderly, the disabled and single-parent families. Moreover, those disadvantaged households are also likely to occupy cold damp properties with inadequate heating systems and poor insulation. The poor quality of such dwellings increases the difficulty of keeping them sufficiently warm.

Fuel poverty is not a term that households will readily apply to themselves. Rather, they can be identified through a number of relevant indicators including:

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[100] EPEE, European fuel Povery and Energy Efficiency. The EPEE project aims to facilitate the application of the European directive on the energy performance of buildings by focusing on low-income people, who often live in uncomfortable dwellings and cannot improve them. EPEE project aims to improve energy efficiency of buildings for people who are victims of fuel poverty. http://www.precarite-energetique.org

- inability to pay energy bills and/or debts to energy supplier(s)
- disconnection or threat of disconnection
- disconnection as a result of perception of the need to ration consumption

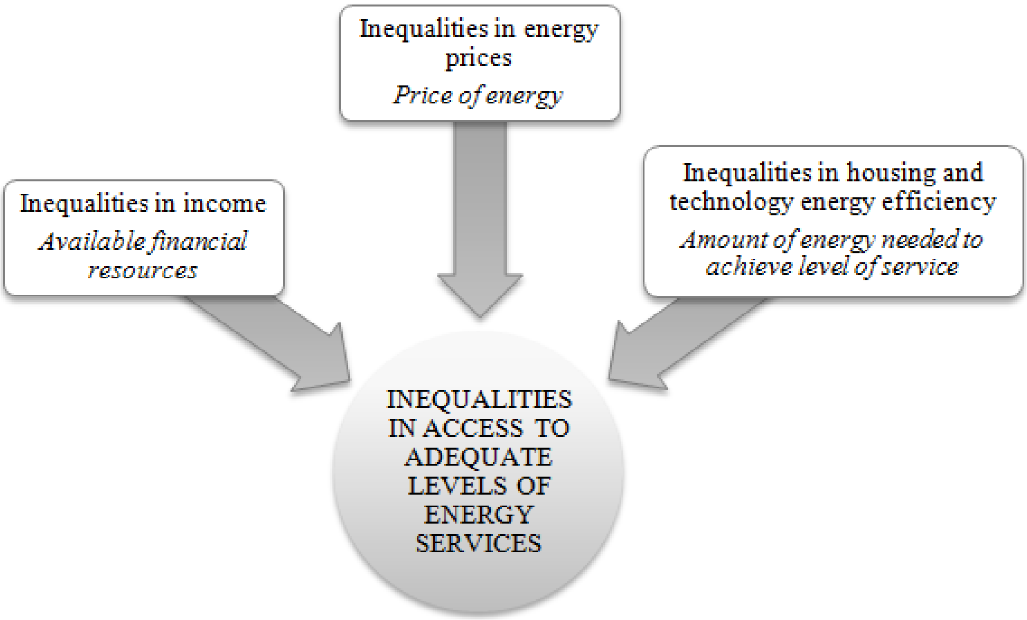
Whilst fuel poverty is an issue for all European countries (between 50 and 125 million people are thought to be affected in Europe), the way in which it is perceived and the measures taken to combat it vary greatly according to the individual countries. In order to better understand and combat energy poverty, the EPEE project begun in December 2006 involves five countries: Belgium, Spain, France, Italy and the United Kingdom.

Three main factors contribute to energy poverty: low household income, inadequate heating and insulation standards and high energy prices. Remedial measures can address all of these factors: social security benefits can be used to assist with energy expenditure and bill payment; discounted energy costs may be provided through social tariffs for vulnerable consumers; financial and practical assistance may be available to improve energy efficiency of the dwelling.

Rising domestic energy prices and the current economic crisis are making fuel poverty an issue of growing concern. Governments are increasingly aware of this problem, which makes this comparative study all the more timely and relevant.

The EPEE project, which has received European Commission funding in the context of the "Intelligent Energy for Europe" programme as well as additional national financial support, has already produced several initiatives, including: the production of guides to best practice; analyses of innovative mechanisms; the organisation of meetings and information exchange.

Figure 8.1: Representation of the three key factors contribute to fuel poverty:



Source: EPEE

B. APPENDIX
THE "FACTOR 4" SCENARIO

The Factor 4 project aims to work out an economic operational tool for social owners in order to favor the integration of energy and GEG challenges in the management plan of their building stock It is a Project partly funded by the EUROPEAN COMMISSION, Intelligent Energy Executive Agency (Grant agreement EIE/05/076/S12.419636) and coordinated by SUDEN[101].

The Factor 4 project is focusing on social housing retrofitting for improving the energy efficiency and the use of renewable energy in order to participate to the reduction of greenhouse gas emissions by a factor 4 before 2050. Its objective is to help social owners to optimize their retrofitting programmers for their whole building stock and to set up strategies towards energy efficiency and the factor 4. The Factor 4 approach is based on the Lyfe Cycle Energy Cost (LCEC) analysis.

The Factor 4 project follows the Sustainable Development World Strategy, the Kyoto protocol and the European energy policy which is to reduce by a factor 4 energy consumption and greenhouse gas emission in European countries before 2050.

The Factor 4 project aims at:

- helping social owners to set up sustainable energy retrofitting strategies for their whole building stock working out innovative solutions and their experiment for energy retrofitting
- providing technical and economic information for tenants and (small) local professionals on energy efficient techniques
- the promotion of the initial energy performance diagnosis of buildings
- the dissemination and larger use of life cycle (energy) cost analysis
- facilitating the dialogue between social owners and their financial partners.

The Factor 4 project's objective is to help social owners to set up sustainable energy retrofitting strategies for their whole building stock taking into account energy savings

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[101] SUDEN, Sustainable Urban Development European Network, http://www.suden.org/en/suden/

and the reduction of greenhouse effect gas (GEG) emissions towards a factor 4 according to the European policy which is to cut by 4 GEG emissions before 2050.

The life cycle energy cost analysis allows to set out these sustainable strategies because it allows to deal together with energy savings, the reduction of GEG emissions and socio economic issues such as the pay back return for social owners and the reduction of charges for tenants.

The Factor 4 approach for setting sustainable strategies for energy retrofitting of social housing building stocks and at territorial scales. The Factor 4 approach allows to reach the factor 4 level and to identify the necessary technical and economic means.

The Factor 4 approach is for various actors:

- for social owners for setting up strategies for their buildings and their whole building stock
- for local authorities and public administration for territorial strategies: for identifying the needed level of subsidies for social owners, for setting regulation or rules, for regeneration projects at the neighborhood or city scale, etc.
- for banks for defining financial rules
- for building companies and industriales in order to better know and so to anticipate the future development of technologies, which brings a better local know how and competitiveness.

The Factor 4 approach is focused on a life cycle energy cost (LCEC) analysis and made of the 3 following phases:

- Phase 1: a building typology for selecting the representative buildings of the building stock
- Phase 2: the building scale analysis: analysis of each representative building and optimization of their energy retrofitting programme with the life cycle energy cost Factor 4 model, with 3 optima together: an ecological optimum (reduction of GEG emissions), an environmental optimum (reduction of energy consumption) and an economic optimum (for both the social owner and the tenant).
- Phase 3: the whole building stock analysis in order to set a sustainable energy retrofitting strategy for the building stock identifying the optimized retrofitting programme for each building and for more information on the Factor 4 approach, read or download the deliverables or contact us.1 Reaching the factor 4 means to divide CO2 emissions (and so energy consumption) by 4 after retrofitting works.

C. APPENDIX HYPOTHESES OF SCENARIOS

Table 8.1: Hypotheses of scenario Baseline, given by expertise EDF R&D

Scenario BASELINE

INSULATION

	Before1950	**Before1975**	**Before2000**	**After 2000**
SFH	Insulation	Insulation	Insulation	Insulation
MFH	Insulation	Insulation	Insulation	Insulation

ENERGY REPARTITION : HEATING

	Électricité	**Gaz**	**Bois**	**Fuel**	**Autres**
SFH	16%	32%	8%	40%	4%
MFH	28%	30%	0%	40%	2%

TECHNOLOGY REPARTITION : HEATING

	Joule	**Thermodinamic**	**Micro cog**	**Condensation**	**Stove**	**Pellet**	**LT**	**Condensation**
SFH	90%	10%	98%	2%	99%	1%	95%	5%
MFH	90%	10%	98%	2%	99%	1%	95%	5%

ENERGY REPARTITION : HOT WATER

	Électricité	**Gaz**	**Fuel**	**Autres (Solaire)**
SFH	29%	32%	0%	39%
MFH	30%	30%	0%	40%

TECHNOLOGY REPARTITION : HOT WATER

	Joule	**Thermodynamic**	**Micro cog**	**Condensation**	**BT**	**Condensation**
SFH	95%	5%	98%	2%	95%	5%
MFH	95%	5%	98%	2%	95%	5%

PENETRATION RATE OF RENEWABLE ENERGY

	Photovoltaic	**Micro wind**	**Temperature**
SFH	10%	1%	19
MFH	5%	0%	19

Table 8.2 : Hypotheses of scenario No Fuel, given by expertise EDF R&D

Scenario NO FUEL

INSULATION

	Before1950	Before1975	Before2000	After 2000
SFH	Insulation	Insulation	Insulation	Insulation
MFH	Insulation	Insulation	Insulation	Insulation

ENERGY REPARTITION : HEATING

	Électricité	Gaz	Bois	Fuel	Autres
SFH	38%	40%	20%	0%	2%
MFH	43%	42%	5%	0%	10%

TECHNOLOGY REPARTITION : HEATING

	Joule	Thermodinamic	Micro coge	Condensation	Stove	Pellet	LT	Condensation
SFH	60%	40%	50%	50%	20%	80%	50%	50%
MFH	60%	40%	70%	30%	0%	100%	0%	100%

ENERGY REPARTITION : HOT WATER

	Électricité	Gaz	Fuel	Autres (Solaire)
SFH	40%	40%	0%	20%
MFH	55%	40%	0%	5%

TECHNOLOGY REPARTITION : HOT WATER

	Joule	Thermodynamic	Micro coge	Condensation	BT	Condensation
SFH	60%	40%	50%	50%	0%	100%
MFH	60%	40%	50%	50%	0%	100%

PENETRATION RATE OF RENEWABLE ENERGY

	Photovoltaic	Micro wind	Temperature
SFH	8%	1%	19
MFH	5%	0%	19

Table 8.3 : Hypotheses of scenario Renewable Energy, given by expertise EDF R&D

Scenario RENEWABLE ENERGY

INSULATION

	Before1950	Before1975	Before2000	After 2000
SFH	Insulation +	Insulation +	Insulation +	Insulation +
MFH	Insulation +	Insulation +	Insulation +	Insulation +

ENERGY REPARTITION : HEATING

	Electricity	Gaz	Bois	Fuel	Autres
SFH	35%	15%	35%	15%	0%
MFH	35%	30%	10%	20%	5%

TECHNOLOGY REPARTITION : HEATING

	Joule	Thermodinamic	Micro coge	Condensation	Stove	Pellet	LT	Condensation
SFH	10%	90%	10%	90%	10%	90%	95%	5%
MFH	10%	90%	10%	90%	0%	100%	35%	5%

ENERGY REPARTITION : HOT WATER

	Électricité	Gaz	Fuel	Autres (Solaire)
SFH	30%	20%	0%	10%
MFH	35%	25%	0%	20%

TECHNOLOGY REPARTITION : HOT WATER

	Joule accumulation	Thermodynamique	Micro cogeneration	Condensation	BT	Condensation
SFH	10%	90%	10%	90%	95%	5%
MFH	10%	90%	10%	90%	95%	5%

PENETRATION RATE OF RENEWABLE ENERGY

	Photovoltaic	SFHcro wind	Temperature
SFH	50%	10%	19
MFH	35%	5%	19

Table 8.4 : Hypotheses of scenario Factor 4, given by expertise EDF R&D

Scenario FACTOR 4

INSULATION

	Before1950	Before1975	Before2000	After 2000
SFH	BBC	BBC	BBC	BBC
MFH	BBC	BBC	BBC	BBC

ENERGY REPARTITION : HEATING

	Électricité	Gaz	Bois	Fuel	Autres
SFH	42%	25%	30%	2%	1%
MFH	48%	35%	5%	2%	10%

TECHNOLOGY REPARTITION : HEATING

	Joule	Thermodinamic	Micro coge	Condensation	Stove	Pellet	LT	Condensation
SFH	40%	60%	40%	60%	20%	80%	50%	50%
MFH	40%	60%	40%	60%	0%	100%	50%	50%

ENERGY REPARTITION : HOT WATER

	Electricity	Gas	Fuel	Autres (Solaire)
SFH	43%	25%	0%	2%
MFH	41%	27%	0%	2%

TECHNOLOGY REPARTITION : HOT WATER

	Joule	Thermodynamic	Micro coge	Condensation	BT	Condensation
SFH	30%	70%	30%	70%	5%	95%
MFH	30%	70%	30%	70%	5%	95%

PENETRATION RATE OF RENEWABLE ENERGY

	Photovoltaic	SFHcro wind	Temperature
SFH	20%	10%	19
MFH	15%	5%	19

D. APPENDIX
THE RESULTS OF SCENARIOS

1. Scenario BASELINE

Figure 8.2: Structure evolution for building stock, subdivided according to the energy used, referred to « Baseline» scenario.

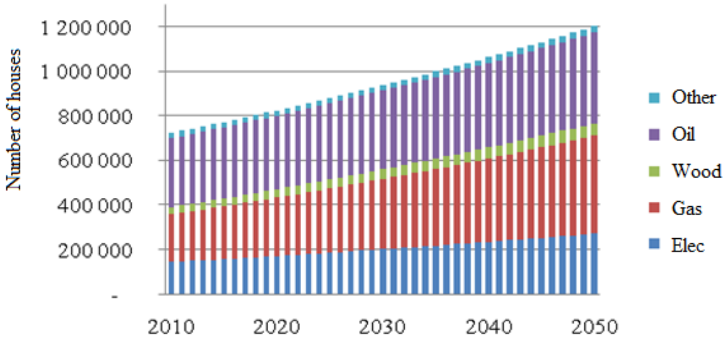


Figure 8.3: Structure evolution for building stock, subdivided according to old efficient, old inefficient and new building stock, referred to « Baseline » scenario.

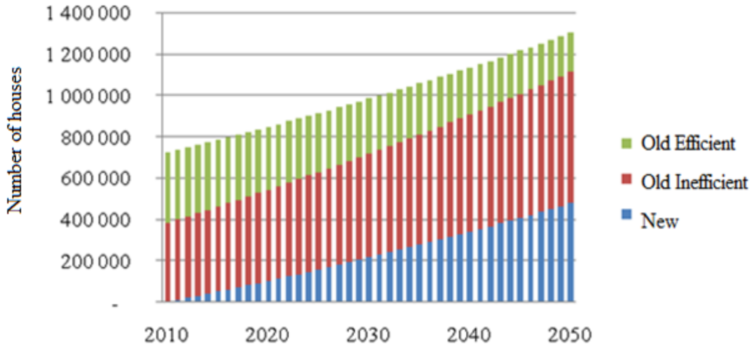


Figure 8.4:Evolution trend of unitary final energy consumption (KWh/house) referred to « Baseline » scenario.

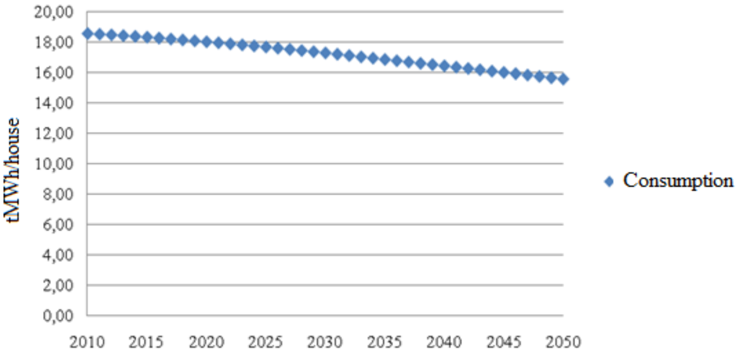


Figure 8.5: Evolution trend of unitary final energy consumption (t eq CO_2/house) referred to « Baseline » scenario.

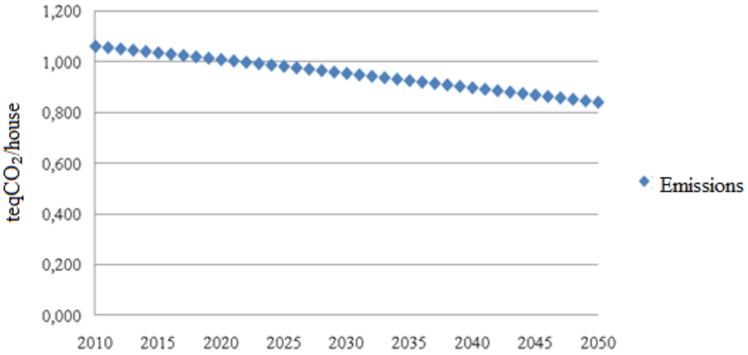


Figure 8.6: Evolution of final energy consumption, subdivided according to the energy used, referred to « Baseline » scenario.

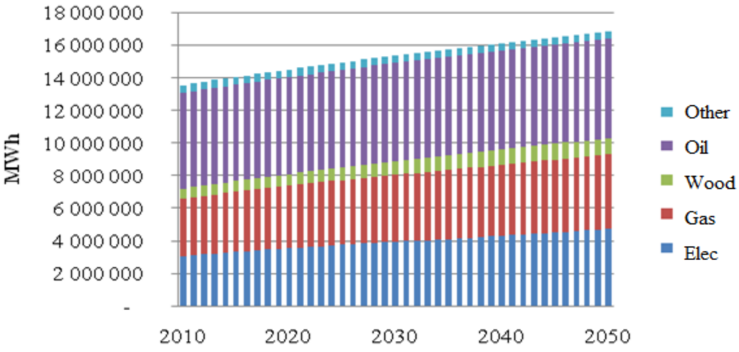


Figure 8.7: Evolution of final energy consumption, subdivided according to the uses, referred to « Baseline » scenario.

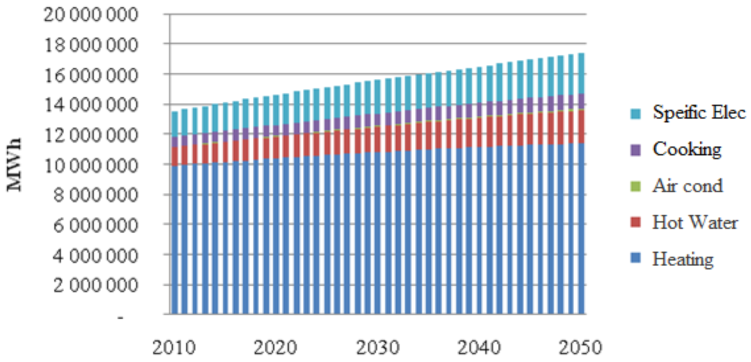


Figure 8.8: Evolution of final energy consumption, subdivided according to the renewable energy uses, referred to « Baseline » scenario.

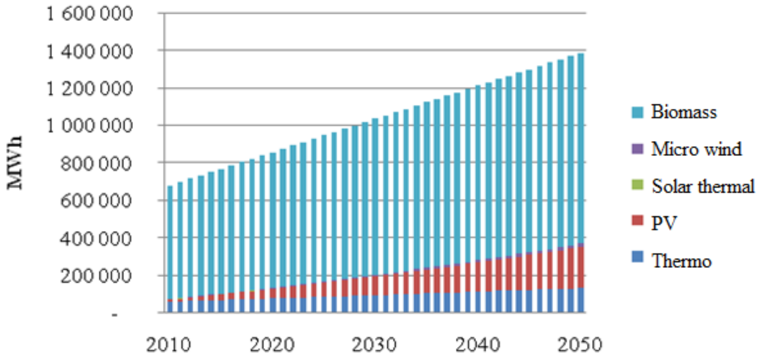


Figure 8.9: Evolution of final energy consumption, subdivided according to old and new buikdings, referred to « Baseline » scenario.

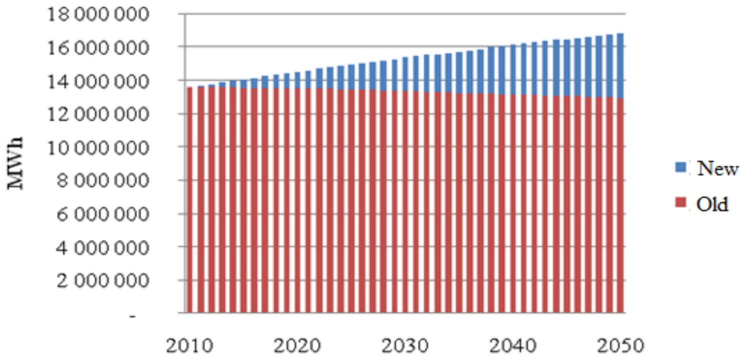


Figure 8.10: Evolution of CO_2 emissions subdivided according to the energy used, referred to « Baseline » scenario.

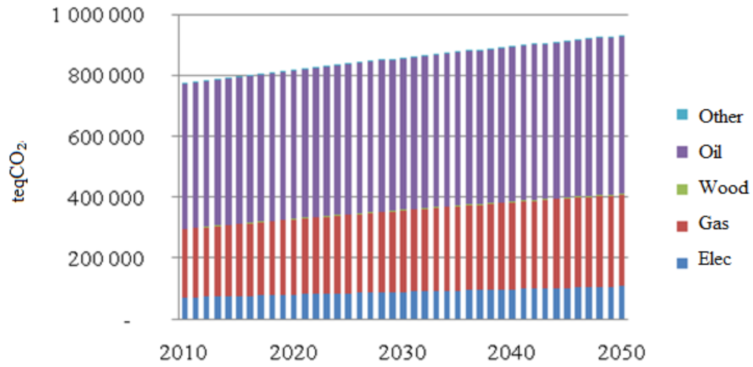
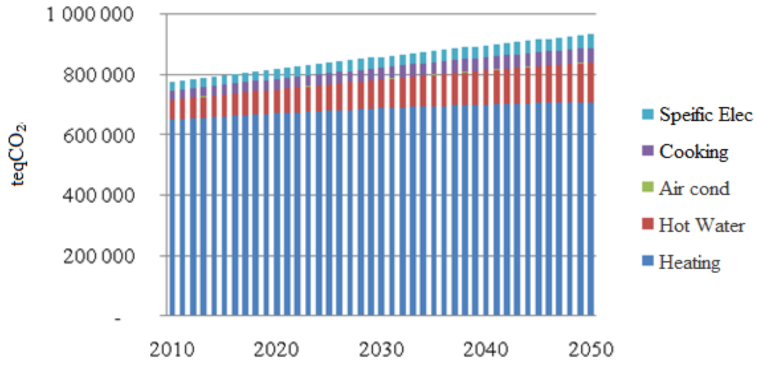


Figure 8.11: Evolution of CO_2 emissions subdivided according to the energy used, referred to « Baseline » scenario.



2. Scenario NO FUEL

Figure 8.12: Structure evolution for building stock, subdivided according to the energy used, referred to « No Fuel» scenario.

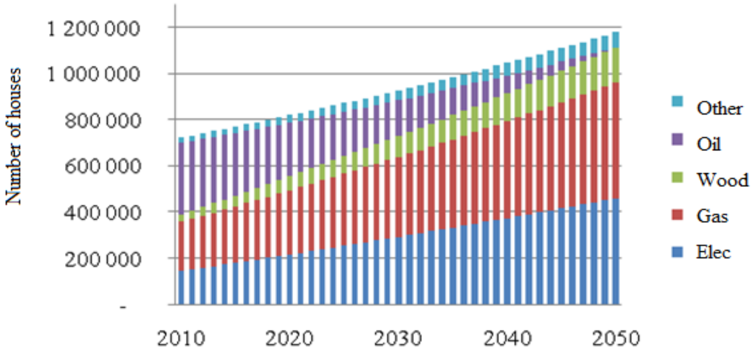


Figure 8.13: Structure evolution for building stock, subdivided according to old efficient, old inefficient and new building stock, referred to « No Fuel » scenario.

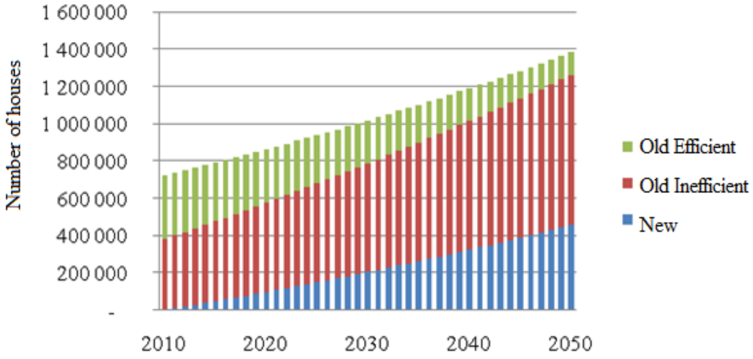


Figure 8.14:Evolution trend of unitary final energy consumption (KWh/house) referred to « No Fuel » scenario.

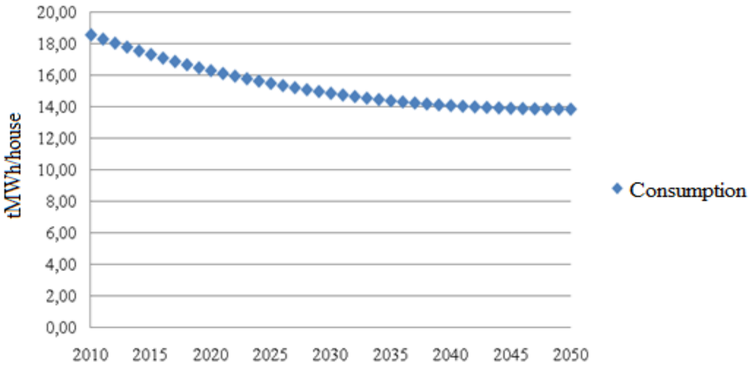


Figure 8.15: Evolution trend of unitary final energy consumption (t eq CO_2/house) referred to « No Fuel » scenario.

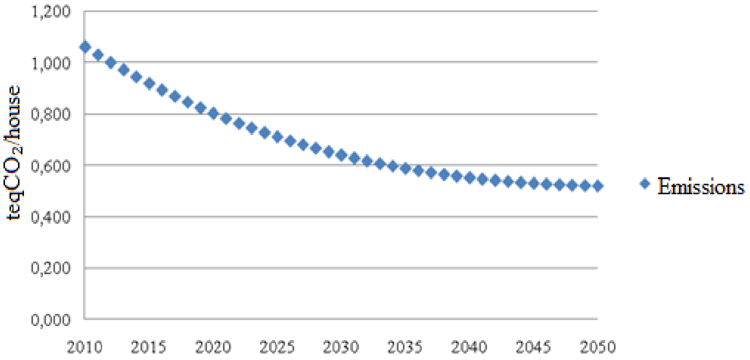


Figure 8.16: Evolution of final energy consumption, subdivided according to the energy used, referred to « No Fuel » scenario.

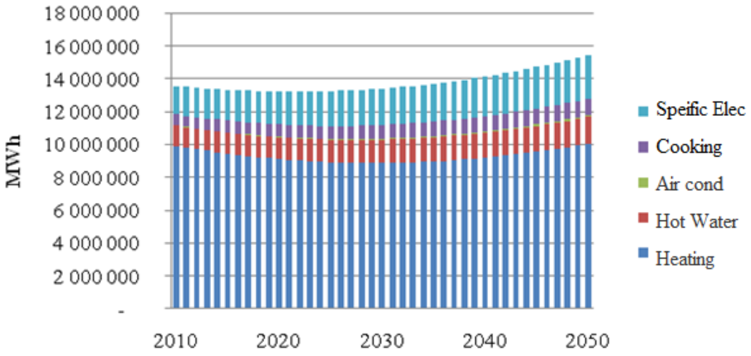


Figure 8.17: Evolution of final energy consumption, subdivided according to the uses, referred to « No Fuel » scenario.

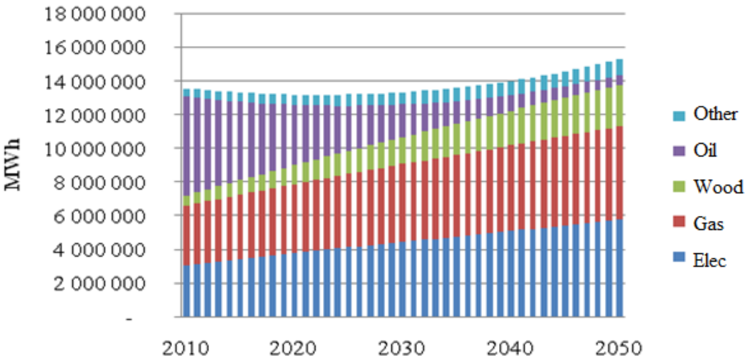


Figure 8.18: Evolution of final energy consumption, subdivided according to the renewable energy uses, referred to « No Fuel » scenario.

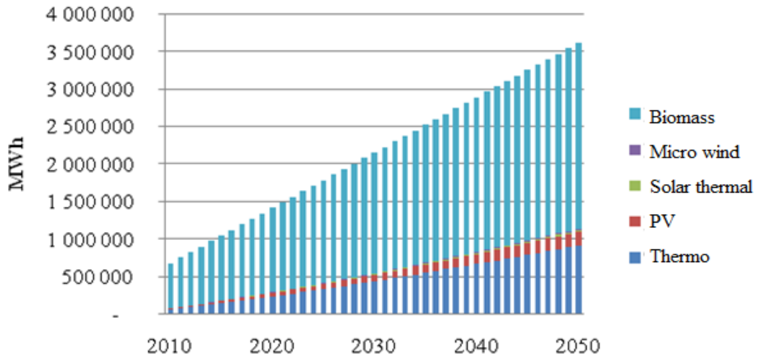


Figure 8.19: Evolution of final energy consumption, subdivided according to old and new buildings, referred to « No Fuel » scenario.

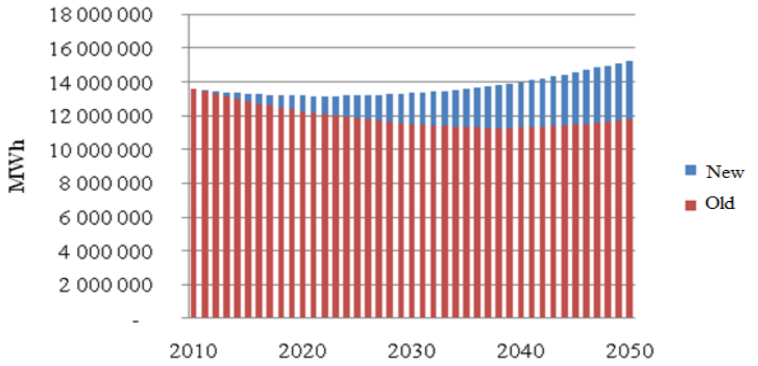


Figure 8.20: Evolution of CO_2 emissions subdivided according to the energy used, referred to « No Fuel » scenario.

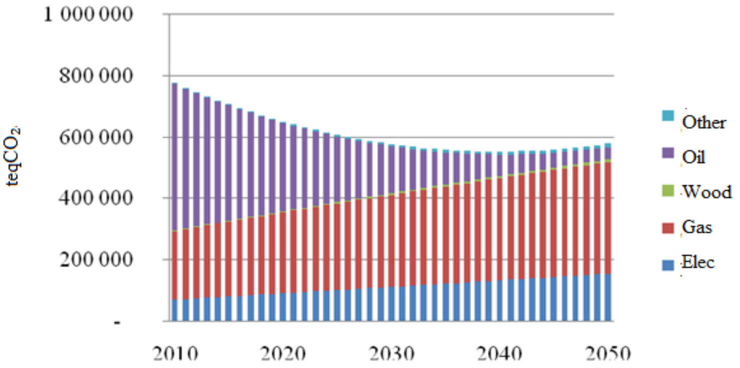
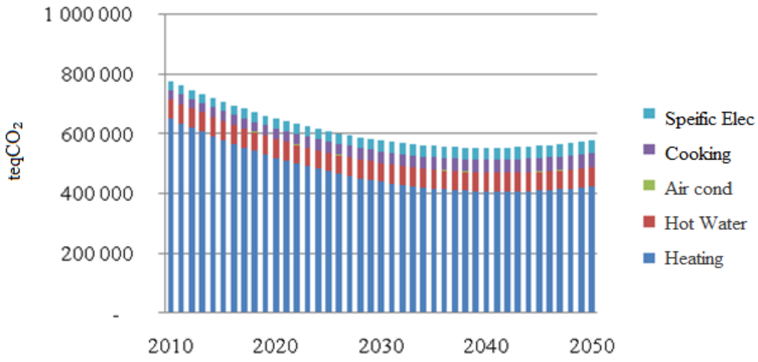


Figure 8.21: Evolution of CO_2 emissions subdivided according to the energy used, referred to « No Fuel » scenario.



3. Scenario RENEWABLE ENERGY

Figure 8.22: Structure evolution for building stock, subdivided according to the energy used, referred to « Renewable Energy» scenario.

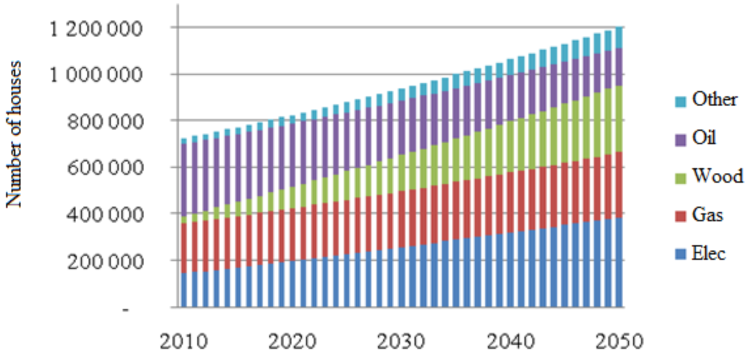


Figure 8.23: Structure evolution for building stock, subdivided according to old efficient, old inefficient and new building stock, referred to « Renewable Energy » scenario.

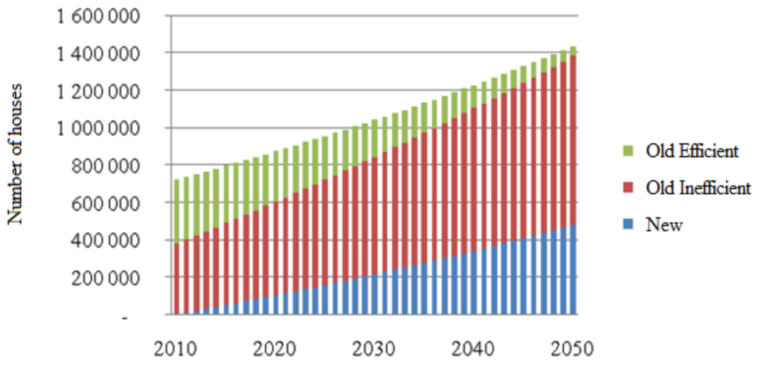


Figure 8.24:Evolution trend of unitary final energy consumption (KWh/house) referred to « Renewable Energy » scenario.

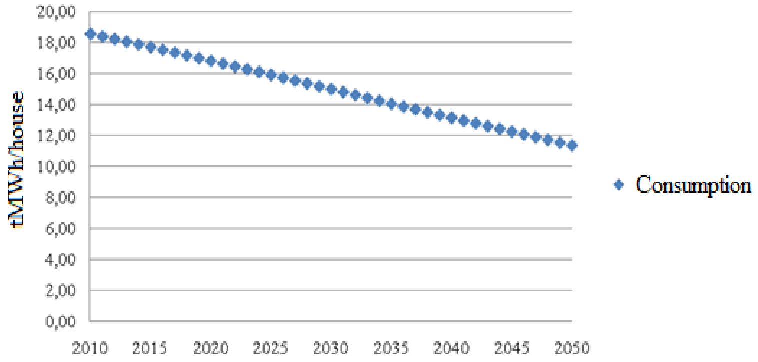


Figure 8.25: Evolution trend of unitary final energy consumption (t eq CO_2/house) referred to « Renewable Energy » scenario.

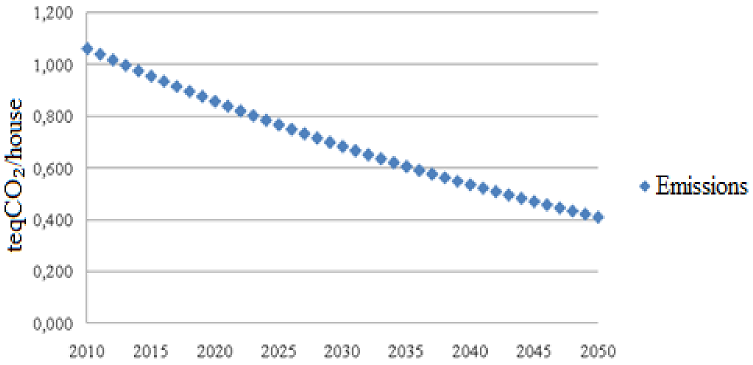


Figure 8.26: Evolution of final energy consumption, subdivided according to the energy used, referred to « Renewable Energy » scenario.

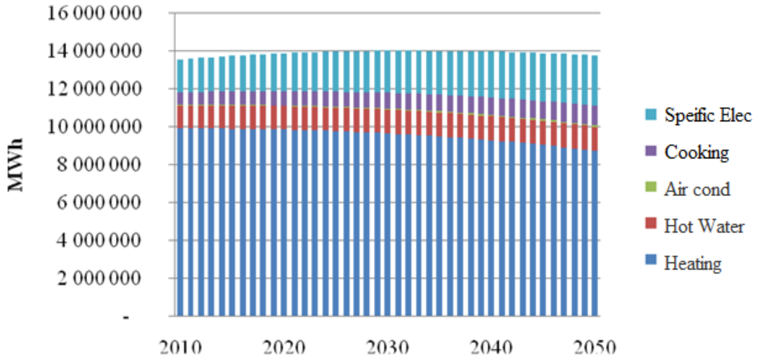


Figure 8.27: Evolution of final energy consumption, subdivided according to the uses, referred to « Renewable Energy » scenario.

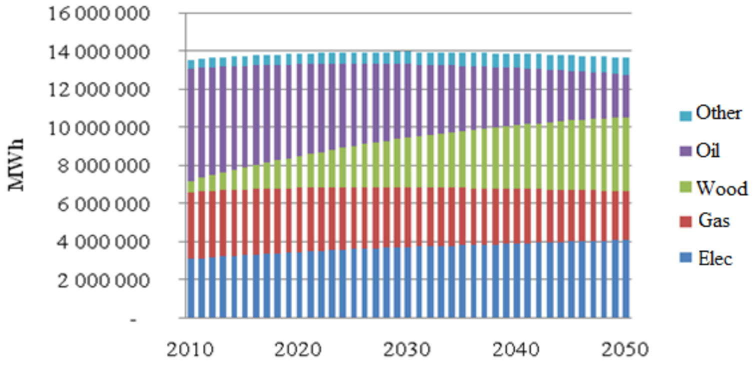


Figure 8.28: Evolution of final energy consumption, subdivided according to the renewable energy uses, referred to « Renewable Energy » scenario.

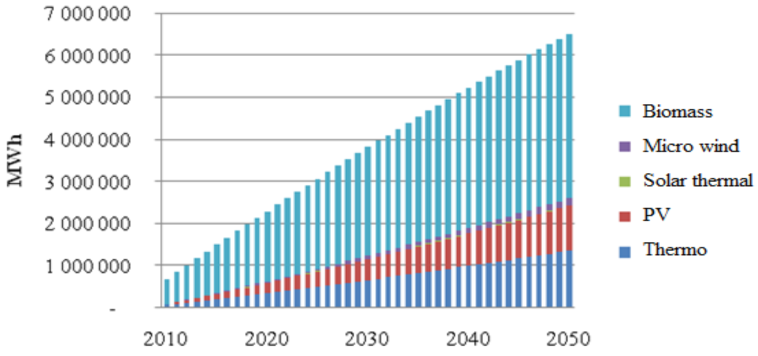


Figure 8.29: Evolution of final energy consumption, subdivided according to old and new buikdings, referred to « Renewable Energy » scenario.

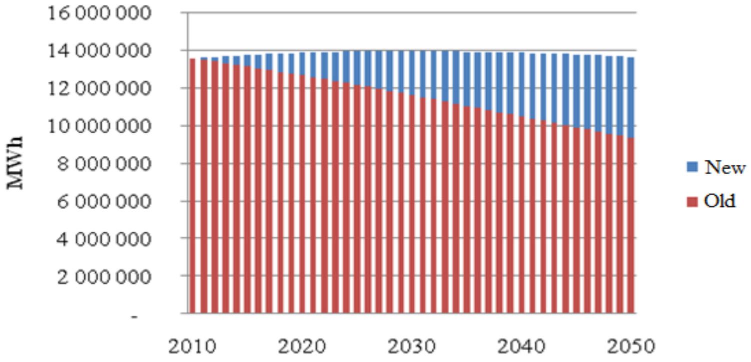


Figure 8.30: Evolution of CO_2 emissions subdivided according to the energy used, referred to « Renewable Energy » scenario.

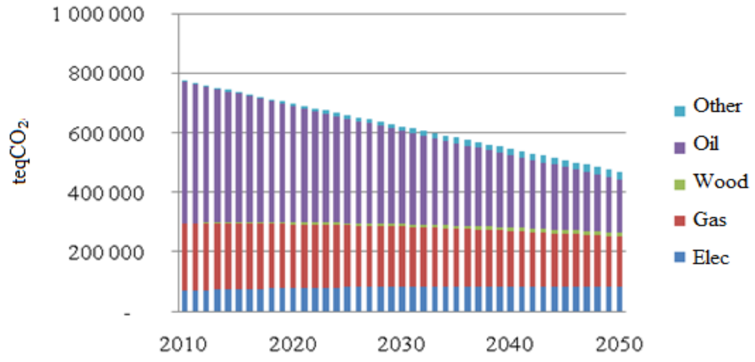
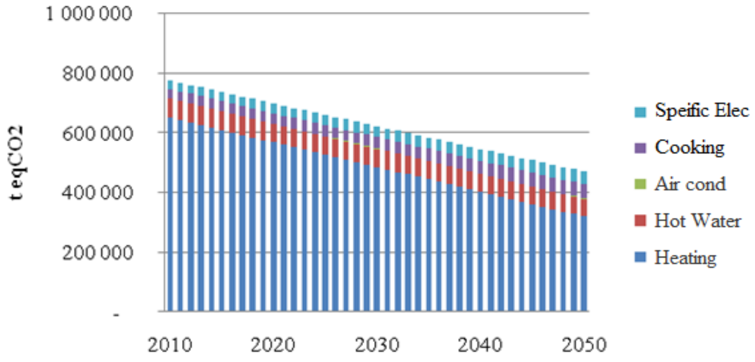


Figure 8.31: Evolution of CO_2 emissions subdivided according to the energy used, referred to « Renewable Energy » scenario.



4. Scenario FACTOR 4

Figure 8.32: Structure evolution for building stock, subdivided according to the energy used, referred to « Factor 4» scenario.

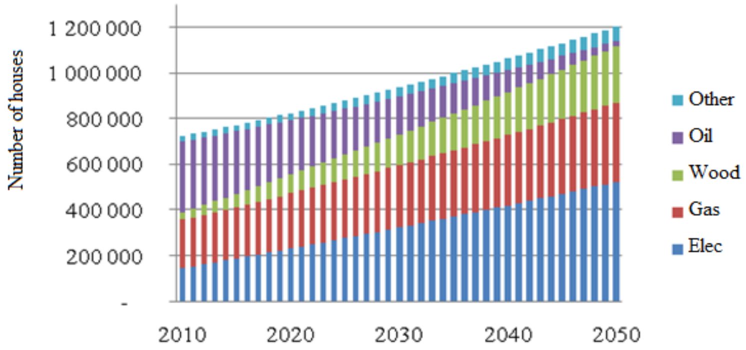


Figure 8.33: Structure evolution for building stock, subdivided according to old efficient, old inefficient and new building stock, referred to « Factor 4 » scenario.

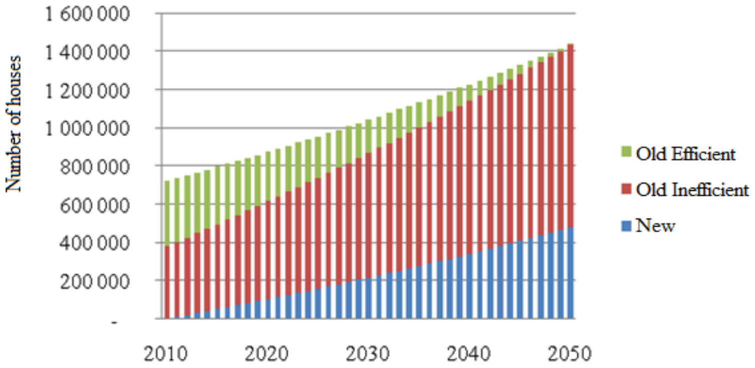


Figure 8.34:Evolution trend of unitary final energy consumption (KWh/house) referred to « Factor 4 » scenario.

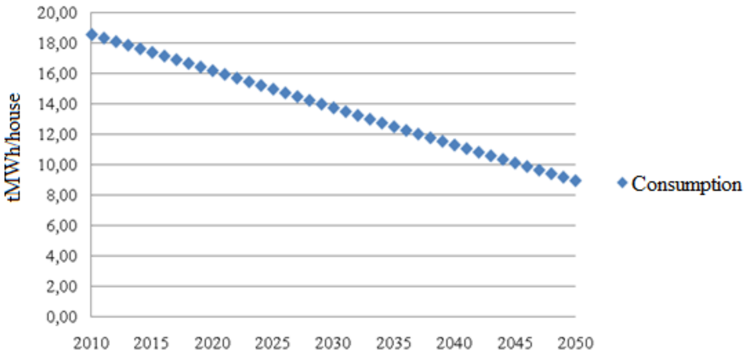


Figure 8.35: Evolution trend of unitary final energy consumption (t eq CO_2/house) referred to « Factor 4 » scenario.

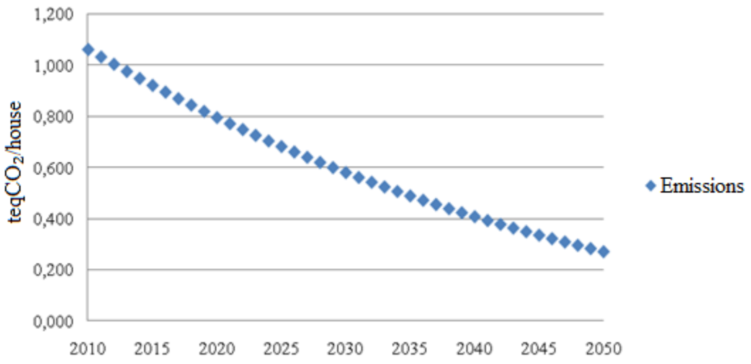


Figure 8.36: Evolution of final energy consumption, subdivided according to the energy used, referred to « Factor 4 » scenario.

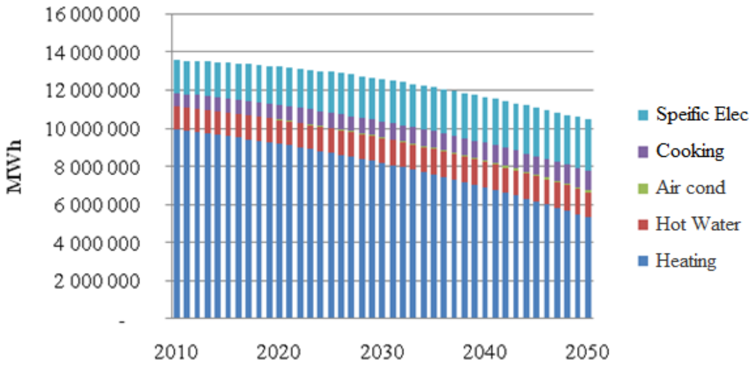


Figure 8.37: Evolution of final energy consumption, subdivided according to the uses, referred to « Factor 4 » scenario.

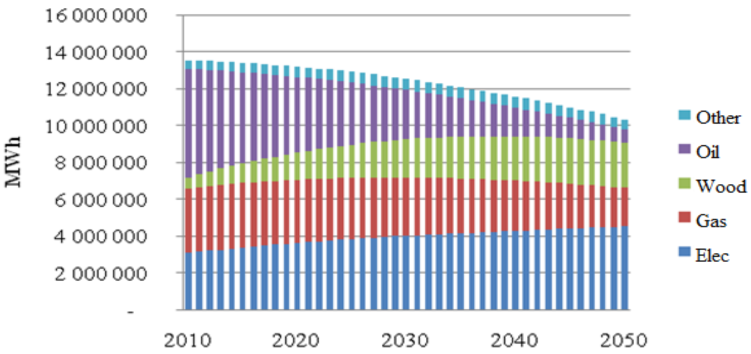


Figure 8.38: Evolution of final energy consumption, subdivided according to the renewable energy uses, referred to « Factor 4 » scenario.

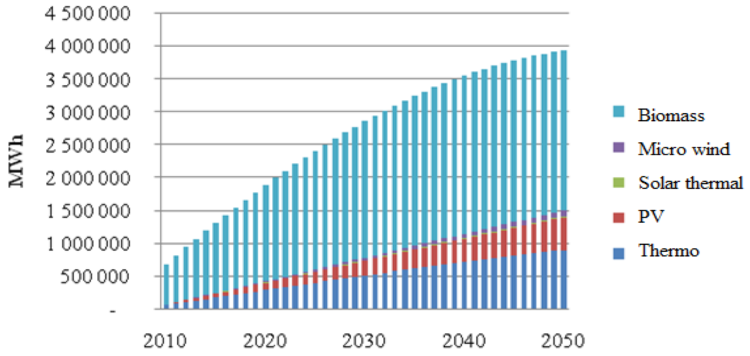


Figure 8.39: Evolution of final energy consumption, subdivided according to old and new buikdings, referred to « Factor 4 » scenario.

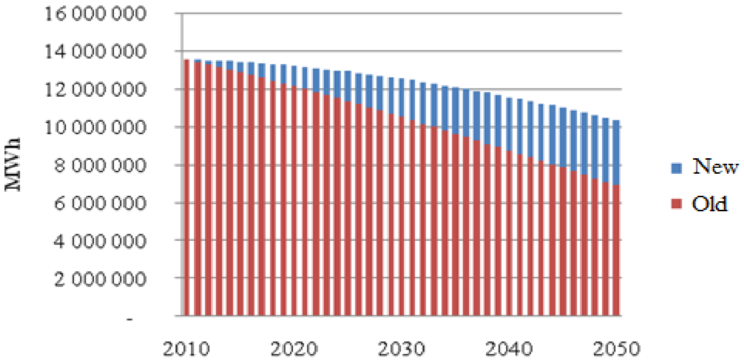


Figure 8.40: Evolution of CO_2 emissions subdivided according to the energy used, referred to « Factor 4 » scenario.

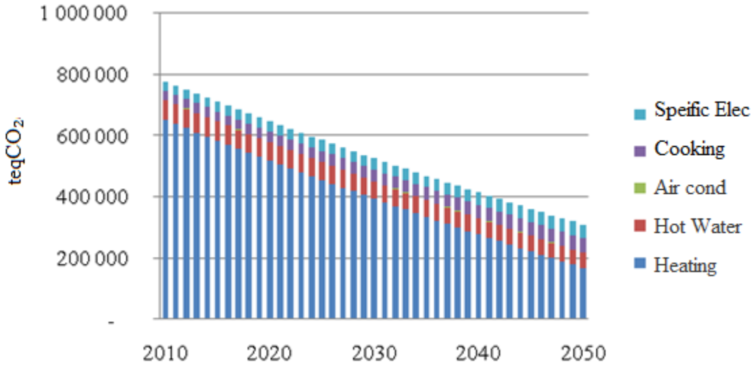
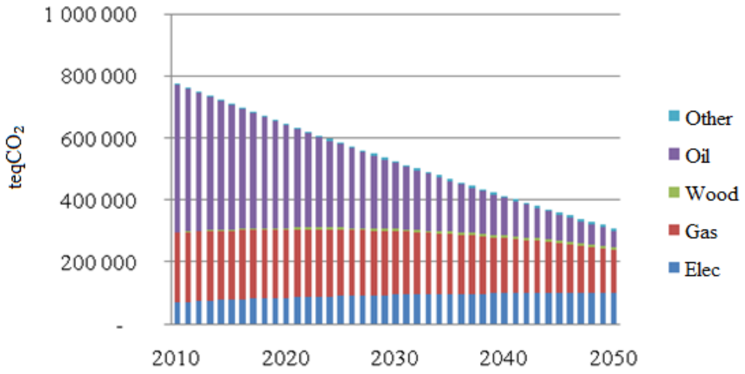


Figure 8.41: Evolution of CO_2 emissions subdivided according to the energy used, referred to « Factor 4 » scenario.



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