# Forecasting white certificate flows with system dynamics

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## Abstract

In France, within the frame of White Certificate scheme, a specified amount of energy savings has to be achieved over three-year periods. The main participants to this system are public authorities, who set the level of energy savings, energy companies, who must reach the target, manufacturers, who develop energy-efficient products and the end-users of the efficient solutions.

The third period of this scheme has started in 2015, with a target of savings of around 700 TWhcumac. This paper is unusual, because it focuses on industry and services, which now count for more than 20 % of the total savings.

The aim of the study is to propose a new methodology to analyze and predict the White Certificates flows in industry and services and give an overview of the preliminary results obtained in this frame. First, the scheme participants were interviewed in depth to identify its main drivers. Then, a system dynamics method was used to split those significant factors in temporal functions such as marketing information, learning effect and financial incentives effect, and to model their evolution. These functions come from the Bass Diffusion Model, which describes the process of how new products are adopted. The challenge was to collect data to calibrate the model, in particular the savings potential for each energy-efficient action, the energy savings flows observed in the past and the commercial incentives over time. The data used for this study come from public authorities (source: EMMY) and the French electricity company EDF.

The first results confirm the significant role of marketing information in the adoption of energy-efficient actions and highlight counter-intuitive side effects such as the impact of financial incentives: they do not seem to be the main drivers, but function as an accelerator role.

With the developed method, it is now possible to split and mathematically describe the main drivers of the mechanism. This is useful to qualify the potential impact that some changes in the scheme could have (update of energy savings actions, new level of obligation, evolution in financial incentives and others). The results given by the model can thus provide guidance for the next regulatory period.

## Introduction

The Energy Efficiency Directive (Directive 2012/27/EU; EED) sets new targets to increase energy efficiency in the EU Member States. The preferred instrument to achieve these new savings is the introduction of energy efficiency obligation (EEO) schemes, frequently also known as "white certificates" (Bertoldi et al. 2010, Lees 2012, Staniaszek and Lees 2012). According to Article 7, paragraph 1 of the EED, energy distributors and/or retail energy sales companies should be committed to new annual energy-savings of 1.5 % of the energy sales by volume, averaged over the most recent three-year period prior to 1 January 2013. Paragraph 9 gives Member States the option of meeting the target using other instruments and measures as an alternative to the energy efficiency obligations. In order to implement Article 7 EED, 4 Member States rely on EEOs alone, 14 use a combination of EEOs and alternative measures and 10 Member States plan to use only alternative measures (Bertoldi et al. 2015). France indicated that almost 90 % of the 1.5 % annual savings required by this directive will be achieved by the White Certificate scheme (Gazeau et al. 2014).

The third period of this scheme has started in 2015, with a target of savings of around 700 TWhcumac[1] (ATEE, 2014). Energy savings achieved in industry and services count for more than 30 % of the total nowadays (DGEC, 2016): our paper focuses on both sectors.

This work was carried out with the technical participation of the French Agency for Environment and Energy Management (ADEME). It is based on a system dynamics method (Sterman J D., 2000), which enables to describe the behavior of non-linear systems such as the White Certificate scheme over time.

Quantitative and qualitative elements were used as inputs for the model: the existing White Certificate flows, coming from an analysis of the White Certificates database (provided by the public authorities with the database EMMY or by EDF), accessible energy saving potentials associated with the most popular energy-efficient actions of the scheme (worked out by EDF) and information coming from interviews of the main participants involved in the mechanism. Thanks to a deep analysis of this data, a system dynamics model was developed to identify and quantify the potential impact that some changes in the evolution of the scheme could have and to provide guidance for the next period. These changes may be the cancellation, update or development of eligible energy saving actions, a new level of obligation or an evolution of financial incentives.

The aim of this paper is to describe a new way of modelling the White Certificates' flows and their evolutions and to give some preliminary results of this modelling.

## Model description

The aim of the model is to build the past dynamics of the White Certificate flows in industry and in services to predict their future flows. The software used to do this is called VENSIM®.

Interviews of the scheme's main participants (public authorities, energy suppliers and distributors, manufacturers and end-users of the efficient solutions) enabled us to have their feedback concerning White Certificates (advantages, drawbacks, impact on their activity, motivation to use this system and others) and thus to identify and select the most significant drivers that should be taken into account in the model. Other factors such as energy prices or regulatory obligations interfere with the White Certificate scheme but were not considered in this first simplified model. They could be added in a second step.

There is no formula commonly used to model the selected drivers in the frame of White Certificates. For this reason, it was decided to use equations which exist in other connected fields of activity, such as the ones used on a Bass Diffusion Model (Bass, 1963) to forecast new products' sales and to adapt them to the White Certificate matter.

1. Energy savings are counted in TWhcumac. This White Certificate energy unit represents the energy savings over the lifetime of the product adjusted with a 4 % reduction rate.

### DATA USED FOR MODELLING

Several kinds of input are used in the model:

1. **Historical White Certificate flows.** Data concerning the achieved flows of White Certificates is provided by public authorities (source: EMMY) and by EDF. By observing what happened in this past, it enables us to get the flow trend curve for each operation.
2. **Energy saving potential.** For each studied action, energy saving potential has been worked out by EDF Research and Development. Two types of potential are calculated: the technical ones (what if all the existing stock of a product was replaced by an energy-efficient one?) and the reachable ones (what is really possible to get, if we take into account some technical-and-economic criteria?) The reachable energy saving potential gives for each action the asymptote, i.e. the "roof-value" that can't be exceeded.
3. **Qualitative information.** The main participants of the mechanism were interviewed. This gave access to qualitative information, useful to identify the main parameters to consider in our model.

With this material (historical data, energy savings calculations and in-depth interviews of the scheme's participants), it was then possible to model the evolution of the White Certificate flows. The principle, given in Figure 1, was to estimate the best way between the two bounds: end of the observed data and "roof-value".

### MODELLING PRINCIPLE: COST AND DISSEMINATION OF INFORMATION

To model the White Certificate flows, it is assumed that the system contributes in minimizing the cost for energy end-users to access reliable information about energy saving actions.

Ten years ago, for an industrial or for a service protagonist, information related to each energy saving action was fragmented, expensive to get and to check. Transaction costs related to the access and approval of information were often too high for small or medium-sized companies, for which energy bills are not the main items of expenditure. One of the biggest interests of the White Certificate scheme is to concentrate and share these information costs between public authorities, ADEME and the obliged parties (i.e. energy suppliers) and to disseminate this information to all potential beneficiaries. As an illustration, the standard sheets of energy saving actions which are suggested by ATEE (French Technical Agency for Environment and Energy) and validated by ADEME and DGEC (French General Direction of Energy Climate) describe eligible energy efficiency actions for each sector, and give an assessment of the associated potential energy gains.

Interviews highlight three main phenomena related to this information. First, the communication initiatives launched by the ADEME and the obliged parties initiate this information about energy saving actions. As this is the case for the advertisement of a new product, attention is attracted thanks to these communication actions. Then, a phenomenon of information dissemination is developed as more and more beneficiaries carry out White Certificate actions. This can for instance occur in seminars about energy efficiency. Eventually, based on the information collected, the creation of a White Certificate flow leads to the development of new business in

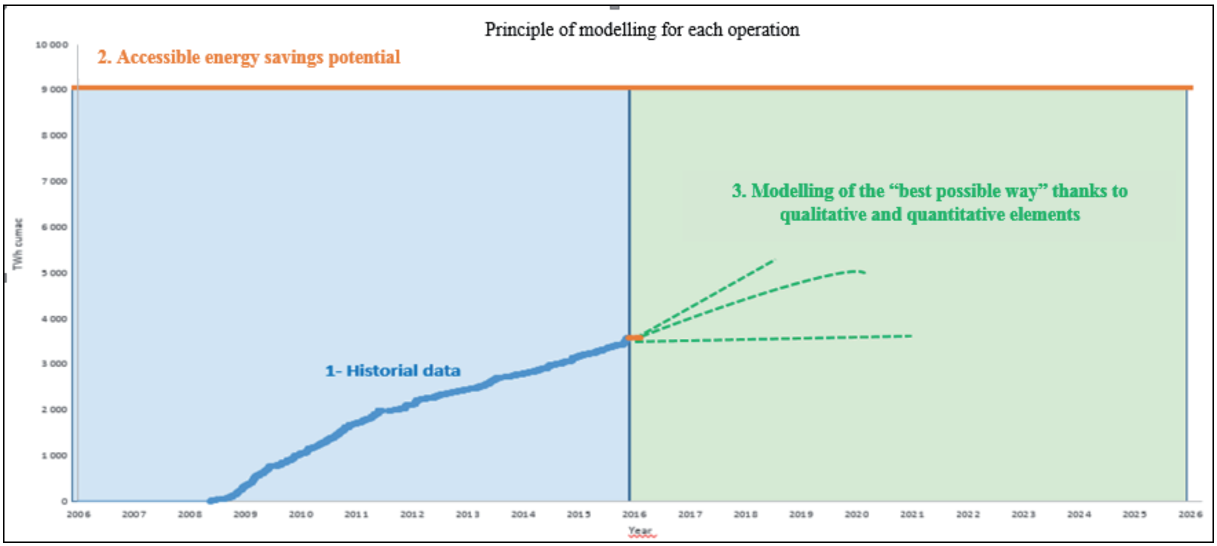


*Figure 1. Principle of modelling for each operation.*

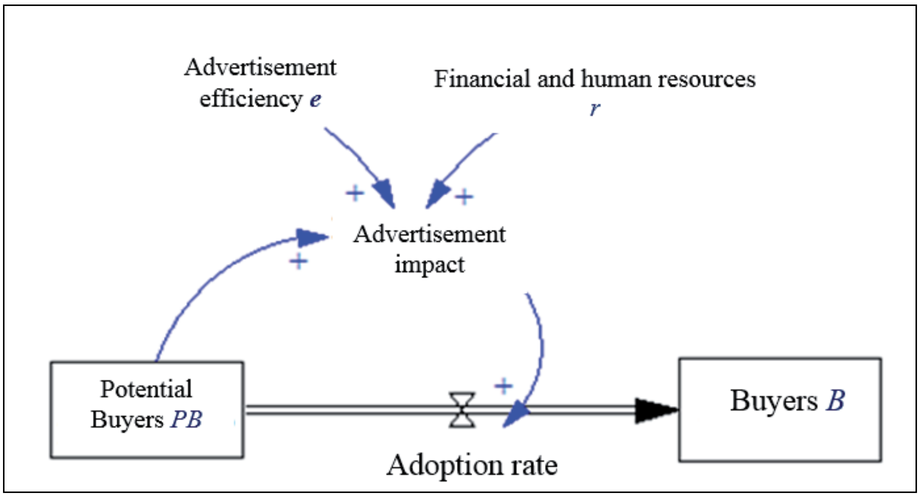


*Figure 2. Parameters with an influence on the advertisement impact.*

the construction, refurbishment and installation companies. This contributes to structure the energy-efficiency sector and to develop an information dynamic among the final customers.

The feedback collected during interviews shows that financial incentives given by the obliged parties play an accelerative role on the White Certificate flows, which are initiated by information, as mentioned above. These incentives reduce the operating costs of an energy efficiency action and, as a mechanical result, increase demand. Therefore, we assume that in industry and services, a financial incentive alone is not sufficient to generate some certificate flows: information diffusion is essential first. This assumption is based on the fact that most White Certificate actions targeting the industry and tertiary sectors are profitable in the actions lifetime. That is compared to investment costs but not necessarily compared to transaction and information costs for small and medium-sized companies which are not specialized in the energy sector.

The following subsections detail each mechanism mentioned above.

#### Information literacy

Bass Diffusion model is commonly used on economic and marketing research to explain the diffusion of new products or technologies (Bass1963). This model describes the dynamics of adoption connected at the same time to the literacy and diffusion of information. It establishes a relevant starting point to model these mechanisms for White Certificates in the long term. The parameters of Bass' model can be evaluated either by analogy with the history of similar innovations introduced into the past, or thanks to the first results obtained when the product enters the market.

First of all, the information literacy within the White Certificate system, by the communication of ADEME and the obliged parties, is thought to be similar to the impact of advertising in Bass' model. The advertising is equivalent to an outside action on a mechanical system. Furthermore, to be effective, it depends on the number of potential beneficiaries, that is a major factor in the White Certificates energy saving potential. If there are no beneficiaries potentially interested, the action becomes inefficient, regardless the allocated resources. This principle is illustrated in Figure 2.

The chosen equation to model this factor is as follows:

*Advertisement impact = PB.e.r*

*PB*: the number of buyers (or beneficiaries) potentially interested (customers with White Certificate energy savings)

*e*: advertisement efficiency (beneficiaries deciding to apply a White Certificate action after having received an outside information from their sector)

*r*: financial and human resources to diffuse the information (from ADEME and the obliged parties on the White Certificate communication campaigns)

In Figure 3, we observe a high initial impact, then a decrease with the reduction in potential buyers.

#### Information diffusion

Information diffusion is also based on Bass' model. It supposes that information circulates then between beneficiaries who carried out a White Certificate action and the interested potential beneficiaries. This information diffusion between the beneficiaries is not exogenous. It depends at the same time on the number of past and potential beneficiaries. We suppose there is a frequency of contact between them and a proportion of these contacts would be transformed into a White Certificate action as shown in Figure 4. It is close to the one used for the epidemic models.

Adoption ratio is the level of uptake. The chosen equation is as follows:

*Word of mouth impact = (c.i.PB.B)/N*

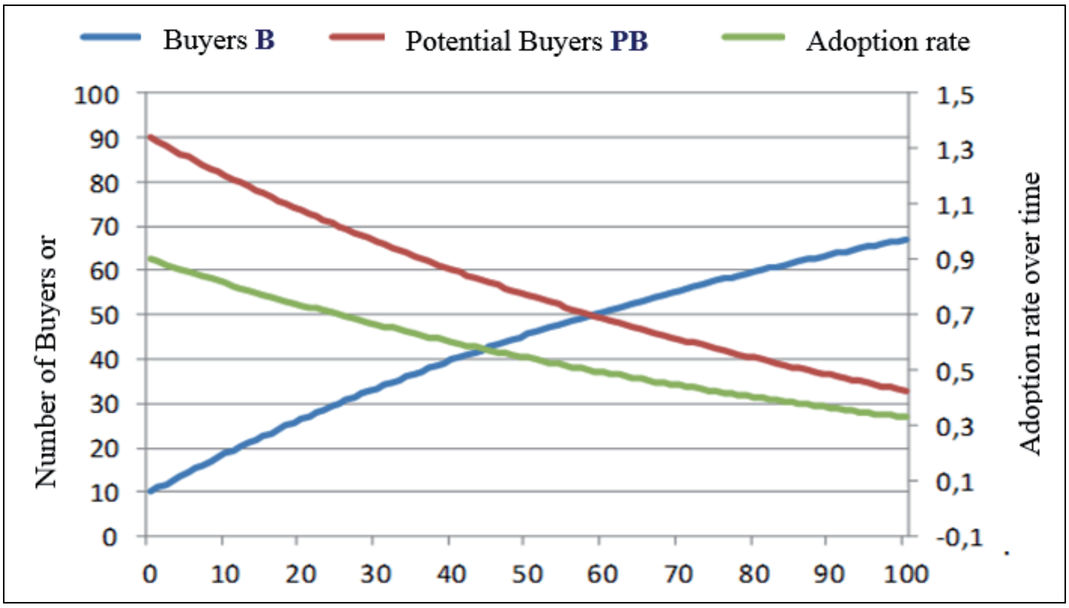


*Figure 3. Advertisement impact.*

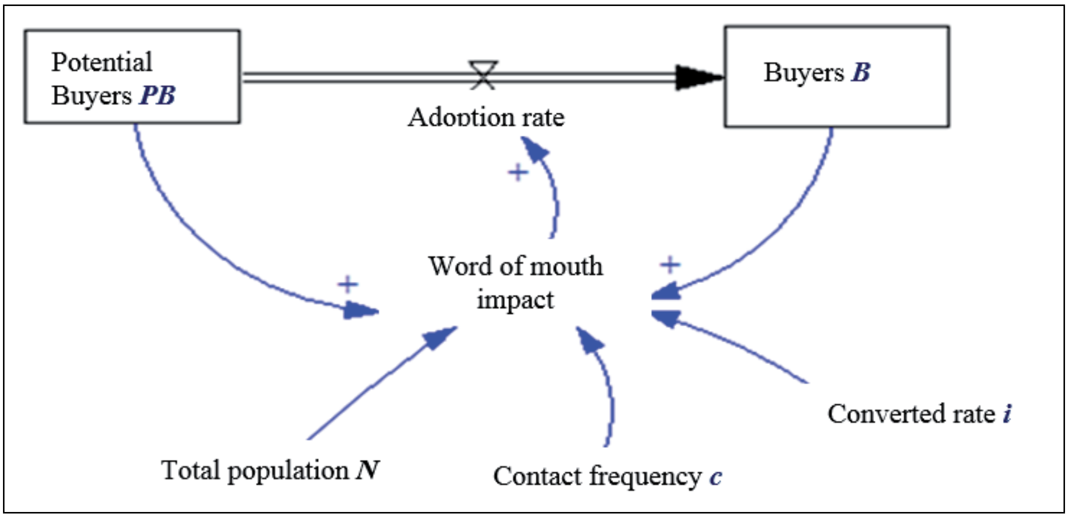


*Figure 4. Parameters with an influence on the "word of mouth impact".*

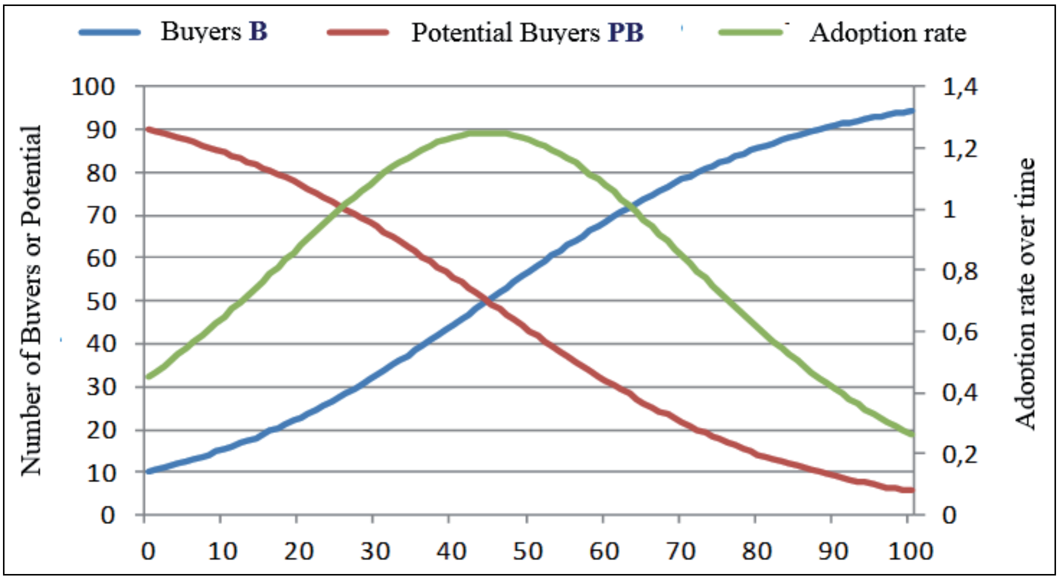


*Figure 5. Word of mouth impact.*

*c*: the frequency of contacts between buyers and potential buyers (e.g. conferences on energy organized by industry associations)

*i*: the conversion rate for every meeting (purchase decision after communication from another beneficiary)

*PB*: the number of buyers (or beneficiaries) potentially interested (costumers with White Certificate energy savings

*B*: the number of buyers having conducted a White Certificate action

$N = PB + B$: total number of beneficiaries covered by the White Certificate action (potential and carried out in the past)

As shown in Figure 5, the adoption rate (equivalent to the flow of White Certificate actions) is in the form of a bell curve. At first, few buyers are present to communicate. Afterward, the maximum of exchanges is reached and at the end potential buyers decline.

### Offer structure

The "offer structure" describes the structure of energy efficient service sector. The proposed service supply on White Certificates actions is more and more organized as actions are actually achieved. This creates a learning effect from carrying out these actions. These mechanisms are represented together according to a logistic curve in the shape of S. This type of curve is usually used to describe a new phenomenon on the market which typically first develops slowly but then accelerates.

The chosen formulation is as follows:

$$\textit{Impact of the structure offer} = \frac{1}{1 + e^{(-v(B-s))}}$$

*B*: the number of buyers having carried out a white certificate action

*s*: offer threshold (from when the number of white certificates carried out is sufficient for structuring an offer)

*v*: offer implementation speed (the amount of time to build a dedicated white certificate offer with the providers and manufacturers)

The theoretical impact graph of the offer structure (Figure 7) shows that the more actions are carried out, the more the offer builds and the effect of learning becomes greater. The threshold represents the value from which the rate of adoption knows an inflection. The speed is the slope of the curve at this point.

### Financial incentives

Financial incentives given by the obliged parties are added as an acceleration phenomenon of the White Certificates' flows.

It is not sufficient at the beginning for the implementation of an energy efficiency action in the industrial and in the tertiary sectors. In fact, the financial incentive causes a price drop for an energy efficiency action.

Supposing that there is a price-elasticity of the request for this action, an increase of the request connected to this price reduction will be modeled according to the estimated price-elasticity, as shown in Figure 8.

The chosen equation is as follows:

$$D = \propto * P^{\varepsilon}$$

$$D' = \propto * P'^{\varepsilon}$$

$$D' = \propto * (P * (1{-}1C))^{\varepsilon}$$

$$D' = \propto * P^{\varepsilon} * (1{-}1C)^{\varepsilon}$$

$$D' = D * (1{-}1C)^{\varepsilon}$$

$$\frac{D'}{D} = (1{-}1C)^{\varepsilon}$$

**Financial incentive impact** = $(1{-}1C)^{\varepsilon}$

D: Request in White Certificate actions *before* the financial incentive

D': Request in White Certificate actions *after* the financial incentive

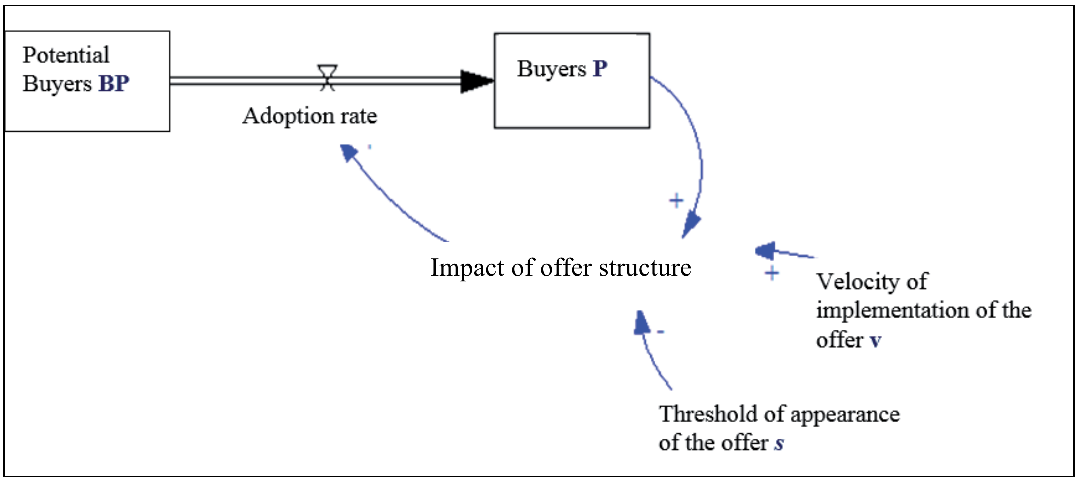


*Figure 6. Parameters with an influence on the offer structure.*

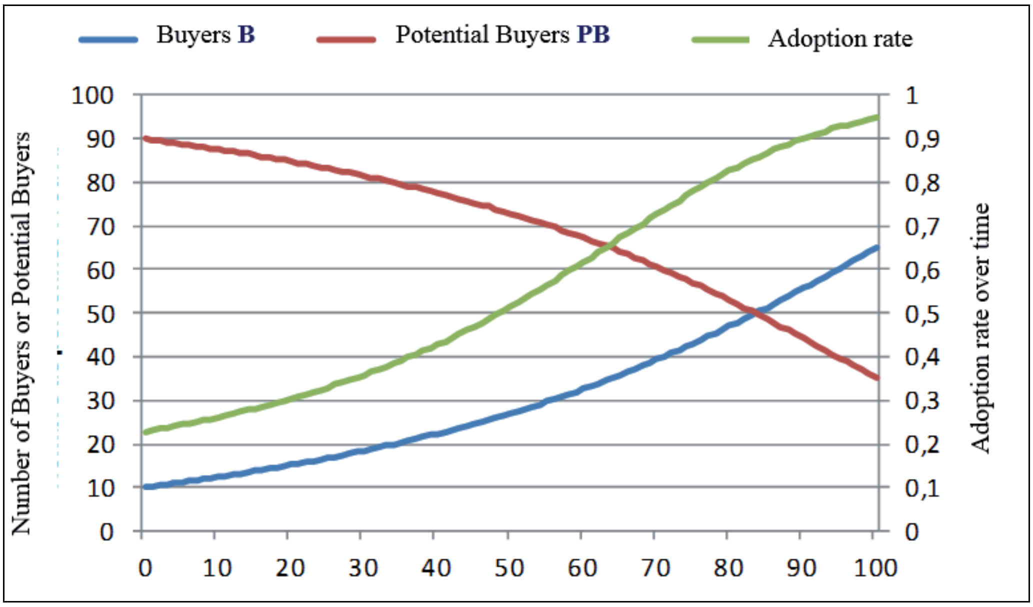


*Figure 7. Impact of the offer structure.*

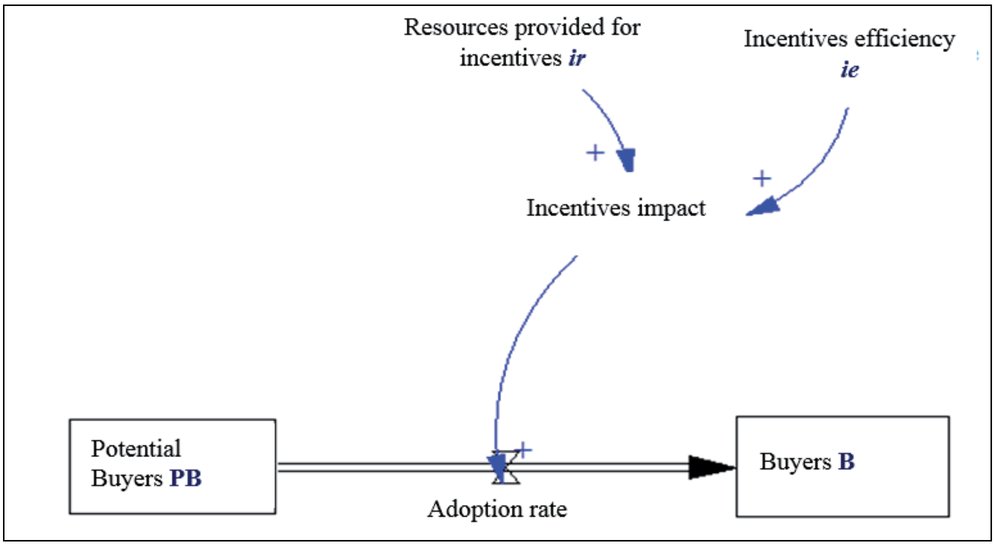


*Figure 8. Parameters with an influence on the incentives impact.*

P: Price of a White Certificate action *before* the financial incentive

P': Price of a White Certificate action *after* the financial incentive

$\propto$: Constant request in White Certificate actions

$\varepsilon$: Price-elasticity of the request (a negative value shows the most logical and the most obvious case, which means if the price increases, the request falls)

IC: Financial incentive, which represents part of the total cost of the White Certificate work (Percentage of the amount of work paid off by the obliged parties)

**Drivers' integration in one global model**

The four drivers described above, i.e. information literacy, information diffusion, structuring of services' offer and financial incentives, are then joined together. It allows us to define an analysis model of the dynamics of the White Certificate actions. This model is specific to each type of White Certificate action studied, which means the constants used for the configuration are specific to each action. The only parameter common to all the operations is the market incentive impact which supposes that the commercial policy in the industry and the tertiary sector is similar.

The final formulation is then obtained to define the adoption rate (White Certificate action flow):

*The adoption rate*

= (advertisement impact + word of mouth impact * offer structuring) * market incentive

*The adoption rate*

$$= \left[PB.e.r + \frac{c.i.PB.B}{N}.\left(\frac{1}{1+e^{(-v(B-s))}}\right)\right].(1-1C)^2$$

PB: the number of buyers (or beneficiaries) potentially interested (customers with White Certificate energy savings)

e: advertisement efficiency (beneficiaries deciding to apply a White Certificate action after having received an outside information from their sector)

r: financial and human resources to diffuse the information (from ADEME and the obliged parties on the White Certificate communication campaigns)

c: the frequency of contacts between buyers and potential buyers (e.g. conferences on energy organized by industry associations)

i: the conversion rate for every meeting (purchase decision after communication from another beneficiary)

B: the number of buyers having conducted a White Certificate action

N = PB + B: total number of beneficiaries covered by the White Certificate action (potential and carried out in the past).

s: offer threshold (from when the number of white certificates carried out is sufficient for structuring an offer)

v: offer implementation speed (the amount of time to build a dedicated white certificate offer with the providers and manufacturers)

IC: Financial incentive, which represents part of the total cost of the White Certificate work (Percentage of the amount of work paid off by the obliged parties)

The potential buyers PB (accessible energy savings potential) and the buyers B (completed operations) are then stocks where the White Certificate actions leave and arrive from. Thus there is the adoption rate-time integral previously defined (negative and positive). As these integral-values are used in the adoption rate formula, we obtain a complex nonlinear system that is solved by iterative steps.

The theoretical graph of the White Certificate flow's evolution (Figure 9) shows that in this fictitious case, non-parameterized example, we see the accumulation of the linked effects to the previous mechanisms. An initial adoption rate is linked to the information diffusion. An acceleration of flows is observed and results from the information diffusion and from the

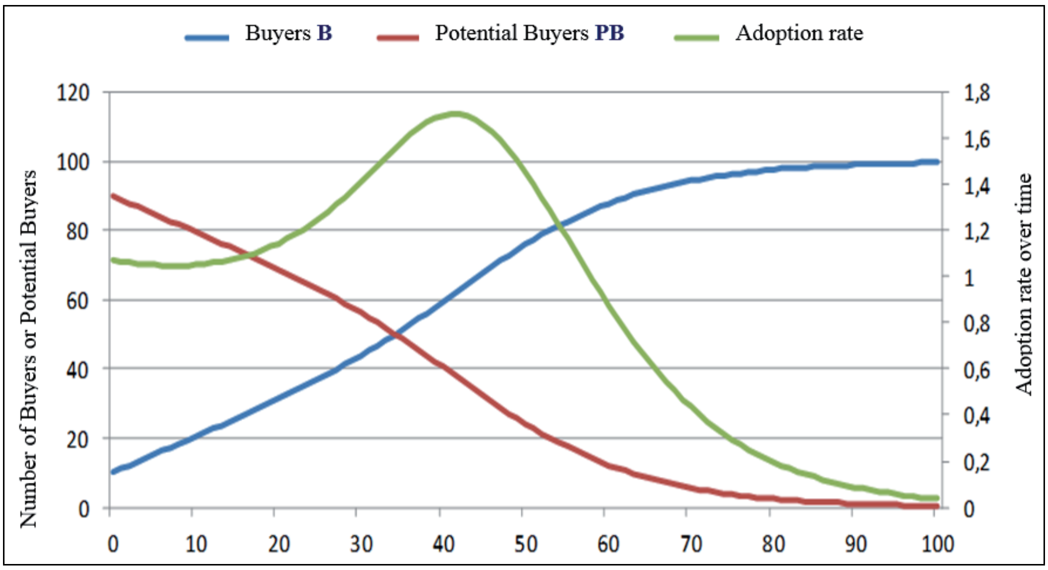


*Figure 9. Theoretical evolution of the White Certificates' flows.*

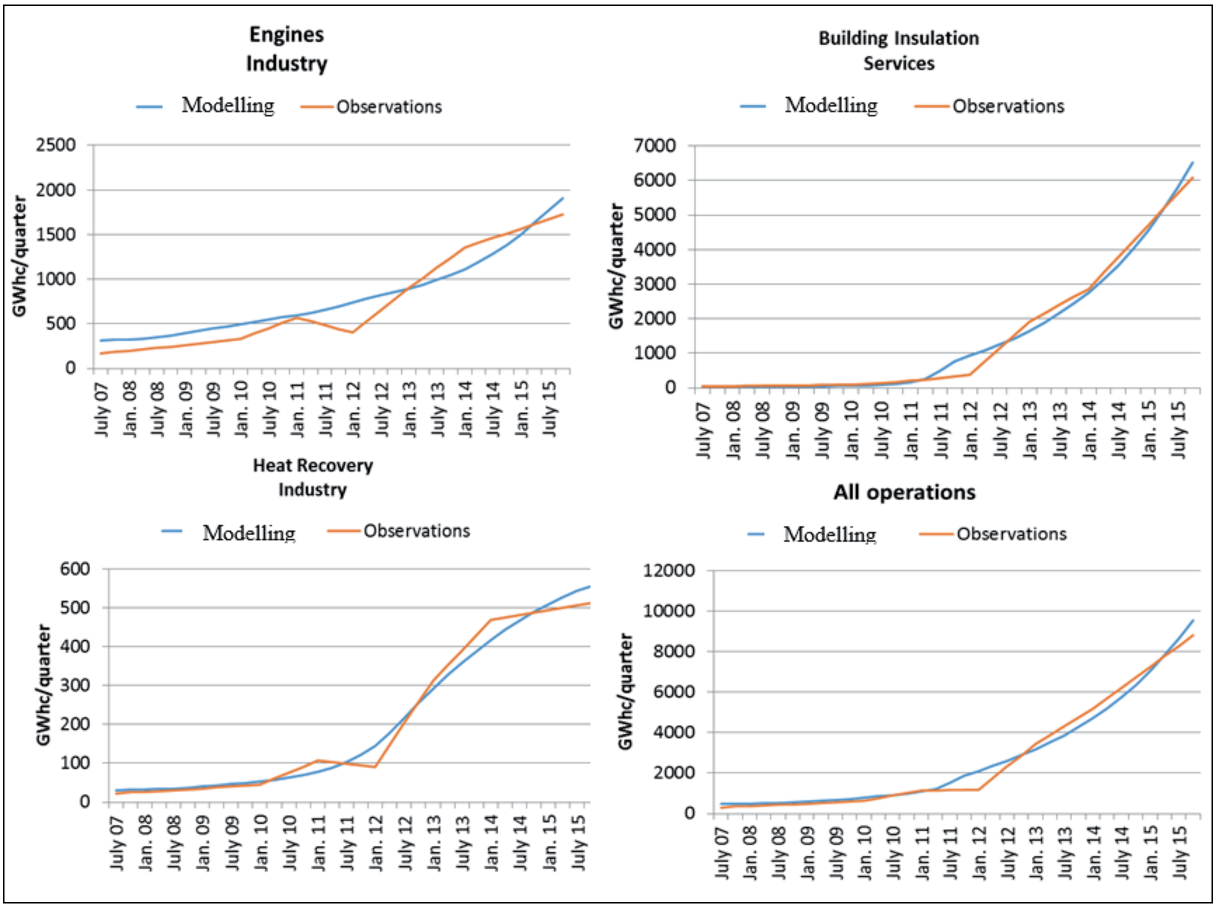


*Figure 10. Adjustment of the model on historical data.*

offer structuring. Afterwards, the accessible energy saving potential is reduced, decreasing the effect of the previous mechanisms until total exhaustion.

## Preliminary model results

### MODEL CALIBRATION WITH HISTORICAL DATA

Exogenous parameters of the model have to be estimated with a calibration step on historical data for each of the energy savings action. Results of the calibration are close to past dynamics, as demonstrated in Figure 10.

### FORECAST OF WHITE CERTIFICATE FLOWS

Once the model has been calibrated, it is possible to forecast flows of energy savings actions under the White Certificate Scheme. With a Business As Usual scenario, without any policy change, the model predicts annual energy saving decisions, for each operation.

Main energy saving actions in the industry will be related to the installation of energy-efficient engines, maintaining the current trend. It is also the case with buildings insulation for the service sector. However, logically the energy efficiency stock for a specific operation progressively diminishes, as most of companies will already have invested in this action.

Consequently, annual energy savings actions decrease over time, after having reached a peak. However, time dynamics of energy efficiency actions vary across operations. Once "low hanging fruits" will have been harvested for energy efficiency, new innovations would be necessary. On the contrary, some operations will need many years to be fully exploited, as illustrated in Figure 11. With the developed method, it is now possible to split and mathematically describe the main drivers of the mechanism.

### MAIN DRIVERS' DECOMPOSITION

System dynamics models are not only useful to forecast future scenarios, but also highlight underlying effects. It is therefore a very useful tool to enhance current energy savings policies for the industry and the service sector. As shown in Figure 12, for the White Certificate scheme, three drivers have a significant impact on annual energy savings according to the model:

- The external information effect is not very important in terms of energy savings flows but it initiates the internal knock-on effect inside an industrial or a service sector, as well as it triggers the creation of a dynamic service offer from manufacturers.
- The knock-on effect, also referred as the "transaction effect", is the addition of three effects: the learning effect, the development of a national efficient energy-saving service offer and the word of mouth effect. It rapidly becomes the most significant leveraging effect.
- Financial incentives are not decisive in the development of an energy-saving operation, but clearly act as an accelerator of the internal diffusion process. The financial incentives are only a small part out of the total investment and

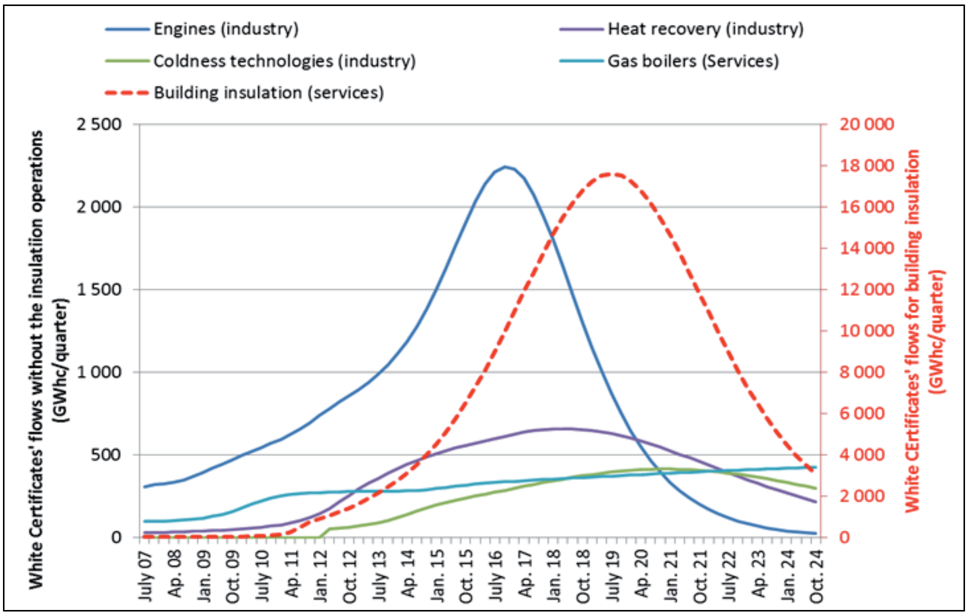


*Figure 11. Flows' forecasts by 2024.*

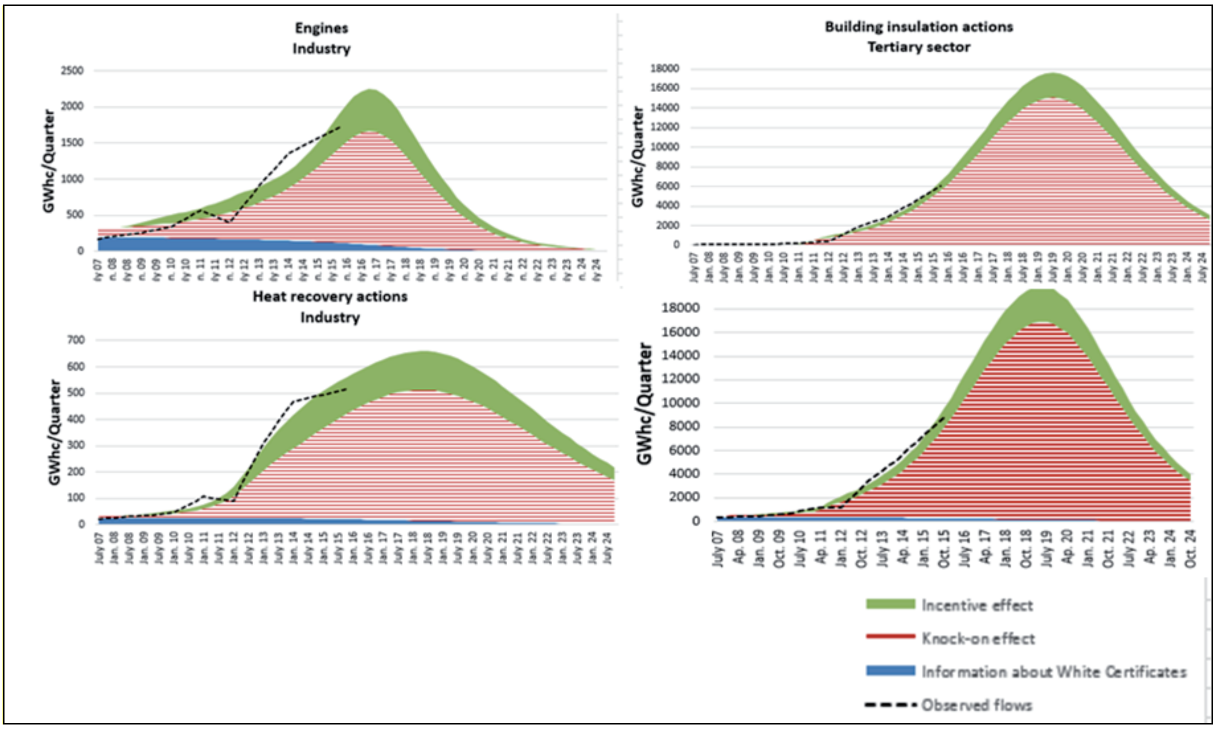


*Figure 12. Underlying factors of the White Certificates' flows.*

thus are not the main driver. On the contrary, transaction costs are massive, above all for small and medium businesses.

#### IMPACT OF FINANCIAL INCENTIVES

In order to demonstrate how the model can be used to test different policy impacts, four scenarios on the financial incentives given by the obliged parties to the beneficiaries are analyzed by changing its financial level from January 2015:

- Business as usual: no change.
- Increase of the commercial incentive by 50 %.
- Decrease of the commercial incentive by 50 %.
- Discontinuation of the commercial incentive.

Results show that Certificates' flows are partially impacted by the level of financial incentives. In addition, discontinuous of financial incentives does not impede other internal dynamics as the development of an industrial ecosystem or the knock-on effect among businesses. The financial impact concerns mainly the rate of energy efficient actions, with a boosting effect on the short-term. However, this effect increases the depletion of the

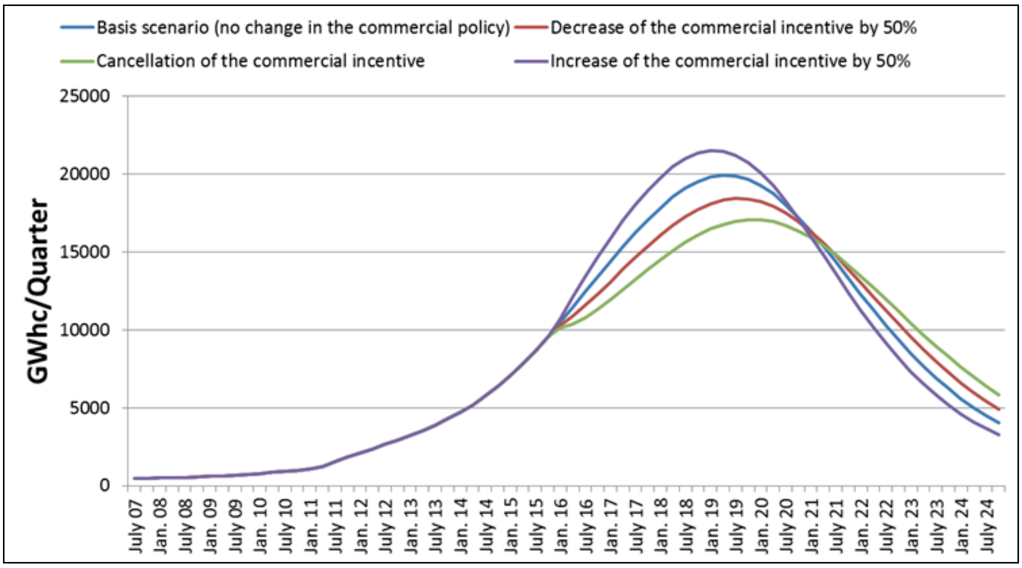


*Figure 13. Incentives' impact on the White Certificates' flows.*

potential stock of energy-efficient actions, reducing the rate in the long term.

This result shown in Figure 13 confirms that transaction costs are the main issue for important energy efficiency operations in the industry and the service sector. On average, the financial incentive only represents 5 to 20% of the total investment required for an energy-efficiency action. However, most of them are already cost-effective in the long-term, but business deciders do not have the means to seek robust and technical information on energy efficiency.

## Conclusion

Energy savings in the industry and the service sector can be simulated with a new model based on system dynamics. This model has been developed using several industry and services interviews and quantified data under the French White Certification scheme.

With the method developed here, it is now possible to separate the main drivers of the mechanism and to describe them mathematically. The first results show that simulations could be helpful in forecasting annual energy efficiency improvements, but also in understanding the impact of policy. This is useful to qualify the potential impact that some changes in the scheme could have (update of energy savings actions, new level of obligation, evolution in financial incentives and others). The forecasts given by the model can thus provide guidance for the next regulatory period.

The point to note is that "knock on effect" is the principal constraint in the diffusion of energy savings operations, much more than financial concerns. Consequently, institutional advertising and certification on energy efficiency operations can significantly boost energy savings for businesses. Financial incentives play only a secondary role into the White Certificate scheme.

This model is a first step for a quantitative analysis of the energy savings flows under the White Certificate scheme. Future evolutions will improve modelling of the other side effects, by taking into account other parameters such as:

- Energy costs.
- Regulatory obligations (such as the energy audit obligation).
- Financial barriers on the implementation of energy efficiency actions for beneficiaries.

In order to continue this work, further studies are being carried out in the frame of a partnership between EDF and Paris School of Economics with the technical participation of the French Agency for Environment and Energy Management (ADEME).

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