Facilitating and evaluating farmer innovations towards more sustainable energy and material flows: case-study in Flanders

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Abstract: *The paper starts from the overal societal concern about the sustainability of energy and material flows, in particular in highly urbanized regions, and the role of agriculture to increase this sustainability. The case of Flanders (Belgium) is taken because of its high throughput of energy and materials. The paper proposes a conceptual and methodological framework for interactively and iteratively clarifying and designing more sustainable systems, investigating how local innovations can be facilitated and evaluated in a consistent way. The innovations are seen as organisation-transcending, as they radically change the interactions between enterprises, organisations and individuals involved (system innovations). The research develops theoretical insights based on action research in case-study settings. Through iterative cycles of observation, reflection, planning and active experimentation, an adaptive research agenda is built, which is orientated towards the local conditions and the major issues of relevance. Besides the more theoretical justification of the –predominantly qualitative- research approach, the paper shows first-stage results on the "rapeseed for biofuel" case, up to now the first-at-hand system innovation in Flanders with respect to more sustainable energy and material flows. A context analysis describes the system innovation through its hardware (technology), software (knowledge, vision, motivation) and orgware (organisational and institutional conditions) and offers a typology of rapeseed producers with different management strategies. This helps to understand why so little farmers engage in cultivating rapeseed in Flanders at the moment, and highlights opportunities for fostering the system innovations' growth/success.*

Keywords: *System innovations, social learning, Flanders, action research, transition science*

Introduction

During the last decennia, the awareness has grown that at present and projected world population levels, the current pattern of human development is not ecologically sustainable. As Giampetro and Pimentel (1993) state: "the world economic system is built on depleting, as fast as possible, the very natural resources on which human survival depends."

The socio-economic system of Flanders (Belgium) is characterized by a high dependency on inputs of raw materials and fossil energy sources (Figure 1). At the same time it generates a large impact on the environment by producing a high amount of waste products and undesirable emissions (e.g. CO_2). As a result the ecological footprint, a measure for the share of bioproductive area a population appropriates (Rees, 1996; Wackernagel et al., 1999), is very high compared to the world average and the sustainable level (5,6 global hectare per capita versus 2,2 an 1,8, data for Belgium and Luxemburg, data for 2006 (Global Footprint Network, 2008)). It means that the Flemish socio-ecologic system has large inputs and output environments and has evolved far away from sustainability. This has negative consequences especially in terms of exhaustion of natural resources, global climate change, and ecological debt towards Southern countries.

Structural changes in society are needed to solve these problems of sustainability. Such changes are sometimes called "transitions". As Rotmans et al. (2000) indicate, transitions occur when developments in cultural, technological, institutional and ecological domains interact and reinforce each other. Transitions do not take place from one day on another. Transitions are gradual processes (Figure 2) which take at least one generation (25-50 years) to bring a system from one dynamic equilibrium to another.

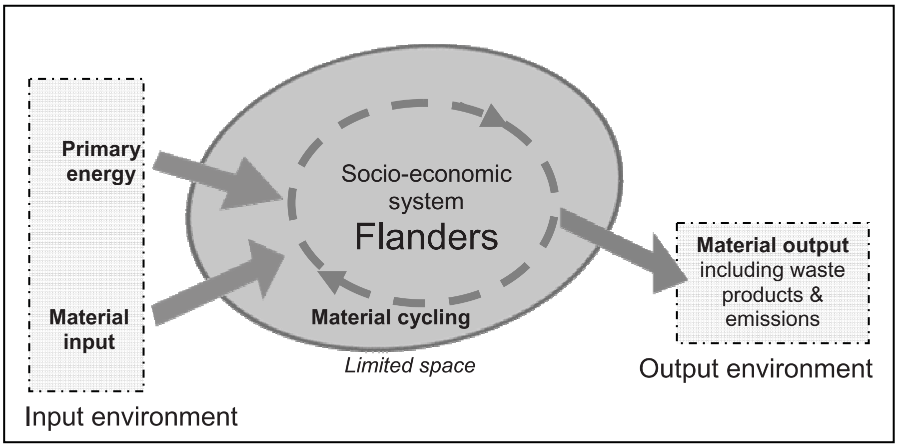

Figure 1. The socio-ecologic system of Flanders.

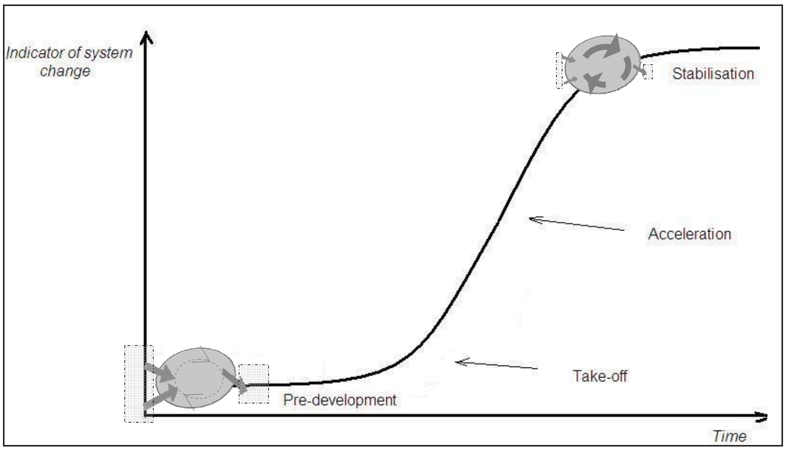

Figure 2. A transition towards more sustainable energy and material flows in Flanders.

Transitions result from system innovations - organisation transcending innovations which radically change the interactions between the enterprises, organisations and individuals involved (Rotmans, 2003) - which themselves stem from product and process innovations. In a transition towards more sustainable energy and material flows in Flanders, there is a need for a decrease in dependency of external non-renewable energy and material inputs and a decrease in unwanted waste-products and emissions, through e.g. an increase in material cycling and use of locally available sustainable energy sources (Figure 2).

Bringing about such structural change and innovation is not something governments can do on their own, but leaving this change to the forces of market is no recipe for sustainability either. Technical and economic perspectives alone are not sufficient to understand how socio-ecologic systems can develop towards more sustainability. As a consequence other perspectives have been put forward: the paradigm of interactivity and dialogue (WUR, 2008). This combines ideas of systems thinking, social learning and multi-stakeholder participation. “Systems thinking” concerns an understanding of a system by examining the linkages and interactions between the elements that comprise the entirety of the system. It brings a holistic and interdisciplinary perspective to complex problems. “Social learning” reflects the idea that the shared learning is a key mechanism for arriving at more desirable futures (Leeuwis and Pyburn, 2002). Innovative solutions are created when diverse stakeholders are able to meet, share experiences, learn together, contribute to decisions and commit to action.

Many actors are involved in creating the problem situation and the participation of many is needed in order to create change. Traditionally the agricultural sector has played an important role in supporting socio-economic flows of energy and material, especially in rural societies. In industrial societies its role in this societal metabolism has diminished because of increased use of fossil energy sources. In the transition towards more sustainable energy and material flows agriculture has regained attention. Indeed farmers can make efforts e.g. to increase material cycling at farm or at collective level, to decrease dependency on external (fossil) energy sources or to provide for renewable energy sources (e.g. by cultivating so-called "energy crops"). Such initiatives offer opportunities for the agricultural entrepreneur, not only to produce in an ecological more sustainable manner, but also to reinforce public support, to increase economic viability and to create new perspectives for the future. At current however innovative initiatives contributing to more sustainable energy and material flows in Flemish agriculture are scarce or lowly visible and their effectiveness debated.

Research aims

The aim of our research is to contribute to the understanding of how system innovations in agriculture contributing to a more sustainable energy and material use in Flanders can be facilitated and evaluated in a consistent way.

In our research we focus on "system innovations". The notion of "system innovation" stems from the literature on transitions science, i.e. interdisciplinary research, aimed at describing and explain broad structural societal changes (transitions) in a coherent way (Ness et al., 1993;Rotmans, 1994;Rotmans et al., 2000;Rotmans, 2003). Transitions result from system innovations which themselves stem from product and process innovations. System innovations are innovations at "system level". The system level is the level the overarching level in which individuals, enterprises and organizations organized themselves and where according to Rotmans (2003) the most stubborn problems are situated. System innovations represent organisation transcending innovations which radically change the interactions between the enterprises, organisations and individuals involved (Rotmans, 2003). A system innovation is thus more than just a change in farm management or an innovation at some experimental farms. It aims at the fulfilment of needs on an entire new manner (VROM, 2001) and stem from a combination of changes in hardware (technology), software (knowledge, vision and motivation of actors) and orgware (organisational and institutional conditions) (Smits, 2002).

The intended output of this research is a generic framework for facilitating and evaluating system innovations towards more sustainable energy and material flows. Therefore, for a selection of cases we will evaluate the possible contribution in the transition towards more sustainable energy and material flows and the potential success and failure factors in facilitating these system innovations. For the latter, the social learning paradigm (see above) will be used as a conceptual framework. An answer is sought to the following questions:

- How can system innovations be evaluated on their contribution for more sustainable energy and material flows in society?
- Which factors and processes promote or prevent involvement and engagement in multi-stakeholder processes for innovation?
- Which factors and processes promote or prevent social learning between actors?

This paper shows first-stage results for one case of rapeseed production for biofuel processing, up to now one of the first at hand system innovations in Flanders in the transition towards more sustainable energy and material flows. A context analysis is carried out in which the hardware, software and orgware components of the system are described. In the next research stage opportunities for its growth will be explored and evaluated through active experimentation. These results wil be compared with the results from other cases.

Research approach

The research develops theoretical insights based on case studies of a selection of (potential) system innovations. Yin (2003) defines a case study as empirical research of a contemporary phenomenon in a real context, which is especially useful when borders between phenomenon and context are not evident. Case studies are in particular useful as a method to build a theory in an inductive way (Eisenhardt, 1989), which is the case for this research project. In fulfilling this goal we are inspired by the principles of qualitative research as developed by among others Glaser and Strauss (1967), Strauss (1987), Eisenhardt (1989) and Yin (2003).

As no single case allows answering the research questions adequately a 'multiple embedded case study design' is chosen to capture a variety of multi-stakeholder settings. Criteria we have defined for the selection of cases were:

- Potential contribution to more sustainable societal energy and material flows.
- Contrasting conditions of soft- and orgware (in order to understand their effects on the effectiveness of the social learning process).
- Differences in potential estimations of "breakthrough" success. System innovations are radical innovations with a high risk for failure. A comparison between successes and failures is most likely to deliver most rich full insights.
- Preference to multi-stakeholder processes in early or more evolved stages of development (e.g. for practical reasons as setting up these processes take a lot of time and effort).

The explorative nature of the research questions is reflected in the choice of research design, referred to as action research. Action research can be described as a family of research methodologies which pursue both action (or change) and research (or understanding) (Dick, 1999). In most of its forms it does this by:

- using a cyclic or spiral process which alternates between action and critical reflection (
- Figure 3), corresponding to Kolb (1984) experiential learning cycle; and
- in the later cycles, continuously refining methods, data and interpretation in the light of the understanding developed in the earlier cycles.

It allows building an adaptive research agenda, which is orientated towards the local conditions and the major issues of relevance. It is thus a type of problem-driven research. The process is emergent and takes shape as understanding increases. The action research generates insights and theory, grounded in empirical data and in action (Eden and Huxham, 1996). By its nature, action research is especially useful for holistic understanding of change processes in complex dynamic real settings, which is the purpose of our research. The assumption is that one cannot understand a human system without trying to change it, since the essential dynamics of the system remain invisible for the passive observer (Schein, 1987).

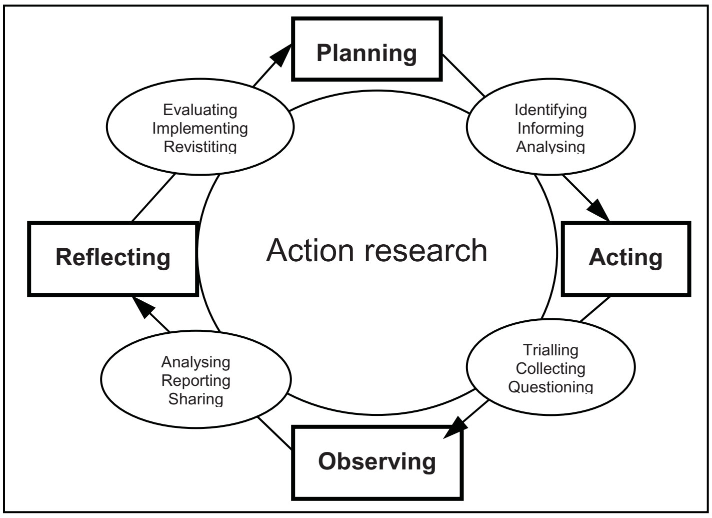

Figure 3. Action research cycle.

The first research phase is aimed at an observation phase according to the action research approach. An initial context analysis is undertaken, including:

- Identification of local systems innovations;
- Identification of stakeholders involved in the innovation process;
- Analysis and description of the soft-, hard- and orgware components of the system innovation;
- Identification of opportunities for fostering the growth/success of the system innovation.

The analysis of the soft-, hard- and orgware component of the system innovation, is based on both quantitative as qualitative information. The hardware analysis stems from literature review (policy documents, scientific and vulgarized publications). The analysis of the soft- and orgware components is based on both documents as well as in-depth interviews with different stakeholders and key-informants, rapeseed growers (5), a representative of a cooperative of rapeseed producers and rapeseed oil consumers (1), representatives of agricultural sector organisations (2) and a representative of a collective of alternative animal producers who mix their animal meal themselves (1). The interviews were semi-structured, and consisted of open-listening and posing open questions (who, what, how, why, when). They took on average two hours, were tape-recorded on tape and transcribed afterwards. Analysis of the data was carried out at the office and consisted of categorizing and conceptualizing of the information. In accordance to Eisenhardt, (1989) and Yin (2003), the validity of the research results was built on secure data triangulation: i.e. cross-checking information by using a combination of research methods (qualitative, quantitative,…) and data sources (interviews, documents,…).

Preliminary results of the rapeseed case

We consider the production, processing and marketing of rapeseed for biofuel applications as a case of a potential system innovation. It involves changing roles of farmers, changing interactions between farmers and consumers and in-between farmers intersectoral (cooperatives of rapeseed farmers) and intrasectoral (livestock producers and rapeseed farmers). In the next paragraphs we will further discuss the hardware (technology), software (knowledge, vision, motivation) and orgware (organisational and institutional conditions) components of this potential system innovation.

Hardware analysis

In accordance with the European biofuel directive, so-called “energy crops” with biofuel applications are promoted by the Belgian government and the Flemish administration of agriculture. The most cultivated energy crop in Flanders today is rapeseed (*Brassica napus* L.). Rapeseed has a high oil content in its seeds which makes it especially useful for biofuel production. The oil can be pressed out the seed using an oil press by the farmer, delivering “pure plant oil”. Rapeseed oil is suitable both for human consumption as well as for fuelling diesel vehicles with adapted engines. The oil can also be chemically transformed into bio-diesel in industrial plants. Biodiesel may be used in pure form in newer engines without conversion of the engine needed. Because of the energy needed during the chemical process, the energy efficiency of the production of biodiesel is slightly lower than those of the pure plant oil (16 GJ/ha compared to 21 GJ/ha (Garcia Cidad et al., 2003)). Using current technology it is obvious that biofuels derived from rapeseed will not make a major contribution in substitution fossil fuels in Flanders. As Garcia Cidad et al. (2003) calculated, at least 90 000 hectares (i.e. 14% of the agricultural area in Flanders) of rapeseed are needed to substitute for only 2% of fossil fuel use in Flanders. The crop is also grown as a winter-cover crop. It provides good coverage of the soil in winter, and limits nitrogen run-off.

Processing of rapeseed for oil production provides rapeseed animal meal as a by-product. The by-product is a high-protein animal feed, competitive with soy (*Glycine max* (L.) Merr.). The feed is mostly employed for cattle feeding, but also for pigs and chickens (though less valuable for these). By using this locally produced rapeseed animal meal, the need for import of soy import, which is an important component in commercial animal meal, can be diminished. From all soy used in the European Union 95% is imported (FAO, 2004). The import of soy bears hidden costs in terms of energy use and land demand and ecological damage. (Paredis et al., 2004) calculated that Belgian livestock sector is supported by around 500 000 ha of soy (data for 2001), mainly produced in Brazil (almost 250 000 ha) and Argentina (some 200 000 ha). This land demand is recognized as one of the pressures for deforestation. Although thorough analysis is missing, replacing the soy by rapeseed oil-cake, the by-product of the oil processing, might make a more significant contribution towards more ecological sustainability than the rapeseed oil itself does by replacing fossil fuels.

Until 2005, cultivation of rapeseed in Flanders has stayed relatively constant and at a low level of some 100 ha. From 2006 onwards the area of rapeseed has increased strongly (in relative terms) towards 891 ha in 2006 and 1185 ha in 2007 (

Figure 4). The share of the rapeseed meant for not-feeding, thus probably for bio-fuel, has increased as well: from 39% in 2003, 58% in 2004, 64% in 2005 and 83% in 2006 (Campens et al., 2006). However, in contrast to the trend of the last years, for 2008 an area decrease is expected, especially because of high grain prizes and suspension of the fallow compulsion regulation (where 54% of the non-food rapeseed in Flanders was cultivated on).

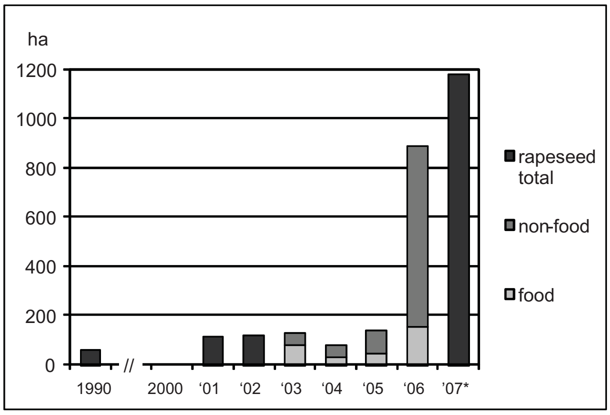

Figure 4. Areal of rapeseed in Flanders and its share of food and non-food applications (preliminary data, source: Federal administration of Economy)*

Software analysis

Despite the relative increase in area during the last years, rapeseed cultivation in Flanders is very low in contrast to the neighbouring regions (Couder et al., 2007). In order to understand why so little farmers do cultivate rapeseed, we interviewed rapeseed growers (5), and other key-informants: a representative of a cooperative of rapeseed producers and rapeseed oil consumers, 2 representatives of agricultural sector organisations involved in the promotion of rapeseed cultivation and a representative of a collective of animal producers who mix their animal meal themselves (because of their potential interest in rapeseed oil cake).

Different management strategies of rapeseed production and their motivations

The individual rapeseed growers that have been interviewed, were rapeseed growers having their own press. Because of the investment in the oil press they show to have made a relative long term decision. Different motivations have led to different management strategies (production, utilization, sales) with different levels of satisfaction (Table 1).

Explanations for low rapeseed production by farmers

These are some major reasons which came out of the interviews why farmers are reluctant for cultivating rapeseed.

- Very high current grain prizes make cultivation of cereals more profitable than cultivation of rapeseed at the moment.
- High transaction costs related with the economic stimuli provided by government:
    - Rapeseed oil for non-human consumption can be sold in Belgium with exemption of excises. This exemption of excise is provided for individual famers or farmers associations pressing own produced rapeseed, for own use or for direct sale to consumers (Campens et al., 2006). This exemption of excise is necessary to keep the price of rapeseed oil beneath market diesel prizes. The ratification procedure (necessary to make use of the regulation) however is a long process which brings a lot of additional administration and discourages interested farmers.
- Uncertain future market perspective of rapeseed derived biofuels.

- Unknown crop with unknown problems, it creates as well local story-telling and gossiping.
- Management difficulties: difficult in rotation with sugar beet: cultivating rapeseed before sugar beet increases the risk for sugar beat diseases.

Table 1. Typology of rapeseed producers.

	Motivation	**Strategy**	**Satisfaction**
Farmer 1	-Belief in future demand of rapeseed products, - Ambition to get the lead on his opponents - Lowering future perspectives of current crop (flax)	- Market-oriented high volume rapeseed oil - Investment cost: high (industrial press), - Economic products: oil, oil-cake and pellets (rest fraction of 1^{St} pressing); at-home-deliverance of oil	Very satisfied.
Farmer 2	- Started as a leisure activity - Side-activity at the multifunctional farm. - Added value to farm tourism activities.	- Locally oriented low volume oil pressing especially for human consumption (deliverance at local shops). - Investment cost: moderate (low volume press). - Economic products: rapeseed oil for human consumption, sold at local food shops (at 3-4 times the price of fuel oil).	Moderately to very satisfied.
Farmer 3	- Substitute for soy in pig feeding, aiming at: * a better pig growth (which had digestion problems with commercial meal), * reduced costs for fodder purchase and a * higher meat prizes in the local ecological butcher's shop, (as no overseas produced soy is used).	- Low volume rapeseed cultivation, incorporated in integrated farming system. - Investment costs: moderate-low, low volume press. - Economic product: oil cake for feed use (major; not for sale), rapeseed oil for fuel, sold at the farm.	Moderately satisfied: *"increasing grain prizes make rapeseed cultivation a bit less interesting now"*.
Farmer 4	- Leisure activity (retired horticultural farmer)	- Low volume rapeseed cultivation and oil pressing - Investment: mediate (medium volume press) - Economic product: rapeseed oil for fuel (major) sold at farm and at a fuel station in the city; oil cake is sold at a relatively low price.	Unsatisfied: low return on investment. He is very interested to form a cooperative of rapeseed producers to achieve a higher return on investment and increase expert knowledge.
Farmer 5	-Idea comes from a small cooperative investing in alternative energy production, which wants to expand its activities, farmers produce at contract prizes.	- Collective low volume rapeseed oil processing of 2-3 rapeseed growing farmers brought together with rapeseed oil consumers in a small cooperative. - Investment costs: low (until now pressing is outsourced). - Economic product: rapeseed oil for fuelling purposes (major); oil cake is hardly sold and at relatively low prices.	The initiators of the cooperative are satisfied about the activities and want to expand it, but find it hard to motivate farmers to grow rapeseed at the moment (high grain prizes).

Orgware analysis

Organisational and institutional conditions create and shape environments in which actors operate and take decisions. From the elements mentioned in the previous sector it can be derived that for the (economic) profitability of rapeseed growing and pressing activities two aspects are of major importance (given investment and operation costs of oil presses):

- Having a substantial rapeseed volume.
- High and secured sales of the main and side products.

Both aspects can be dealt with by improving organisational conditions (let us assume for this analysis the institutional context as given). It is clear that improved interactions between rapeseed growers, consumers and animal producers can contribute to the fulfilment of above-mentioned aims. Given the fact, that farmers or farm organizations can only sell rapeseed oil free of excises from own production, the easiest way to increase rapeseed volume is to find more rapeseed growers and form a cooperative. Moreover a cooperative of rapeseed growers has additional benefits for the members, among others reduction of administrative costs, risk sharing and increased learning. Moreover opportunities for more valorised products and more secured sales are created by improving interactions with consumers of rapeseed oil and rapeseed oil cake (animal producers). As was found during the interviews, rapeseed oil cake is sold under the prices of commercial animal meal (because it is unknown to most animal producers). However as a representative of alternative animal producers declared: "we know rapeseed oil cake is an interesting animal meal component, but we are afraid that the price will be high - because there are little producers- and we don't know where to get it".

Conclusions and future research plans

In this paper a conceptual and methodological framework is proposed for interactively and iteratively clarifying and designing more sustainable systems, investigating how local innovations can be facilitated and evaluated in a consistent way. Informed by a transition perspective on sustainable development, an action research approach is used, which allows for fine-tuning research questions towards more precision as understanding of the phenomena increases. First stage results are presented of a context analysis of the case of rapeseed cultivation for biofuel processing in Flanders, the first-at-hand system innovation in Flanders contributing to more sustainable energy and material flows. The results show that a synergy of changes in hardware (technology), software (knowledge, vision and motivation of actors) and orgware (organisational and institutional conditions) are important for the success of the system innovation. Succes of the system innovation is defined at the software level, when actors are motivated to engage in the system innovation. In order to achieve this opportunities are to be found especially at the hardware level in increasing energy yield per hectare and at the orgware level, in creating stable and lucrative market conditions, removing of administrative barriers and improving cooperation and social learning between involved actors. Following the action research approach, the results of this context analysis form the basis for further planning of future research actions. In the next phase we will investigate (i) which factors and processes promote or prevent involvement and engagement of actors in multi-stakeholder processes for innovation and (ii) which factors and processes promote or prevent social learning between actors. At the same time, other cases for study are being identified and selected, to allow for a comparison between cases.

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