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Designing economic models for the energy transition at the territorial scale

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Abstract: Climate change mitigation and sustainable development is increasingly defining urban projects. High energy performance building standards imply high project extra costs at inception or through retrofitting solutions in urban renovation of buildings and urban infrastructure. However the weak economic climate and outlook is making it hard for investors to justify the additional investments in the absence of a market. Efficacity, the Institute for energy transition in the urban environment proposes an 8-stage methodology in order to identify relevant externalities of an energy efficiency project, determine relevant monetary values and to design suitable partnerships likely to convert them into economic flows. This article reviews this method as applied in a first instance to the specifications of a new building block project based on the use of potential synergies with local facilities (geothermal drilling and nautical centre). A second example reviews the potential economic effects on a district heating network when implementing non-concerted sustainable policies (building energy efficiency actions and waste minimisation policies). The application of this methodology proves it is useful for identifying and valuing externalities. The development of tools for use in partnerships through innovative contractual agreements and transactions intends to integrate the value of externalities in the overall project evaluation and is the main objective pursued by this project.

1. BACKGROUND

Energy efficiency investments have by and large been limited to energy-intensive industries 'contribution to climate change mitigation (Grubb et al., 2014). In urban projects energy efficiency is less concerted and explicit.

With new large urban projects encouraged to integrate climate change mitigation through high energy performance standards, the impact on project costs is considerable. From the additional conception costs to all the other additions in terms of equipment, facilities and infrastructure, energy efficiency implies a considerable increase in costs when constructing a new housing, office buildings or transport infrastructures. This is even more significant in the case of urban renovation (Guenec et al., 2009, Nösperger et al., 2015). However the poor economic outlook is making it hard to justify this additional investment in the absence of a market for these ambitious projects. Yet, social and environmental co-benefits related to energy efficiency are now apparent (Tirado Herrero et al., 2011; Ürge Vorsatz IEA 2014). How can these contradictions between benefits and costs be solved in order to make projects viable? We shall attempt to solve this paradox by addressing a number of questions:

- When assessing the economic opportunity of an urban project, how can it be ensured that the socio-environmental benefits related to improved energy efficiency are taken into account? How are these benefits qualified from the perspective of different stakeholders and monetised, when relevant?
- What types of partnerships, agreements or contracts exist which ensure an equitable distribution or sharing of the economic value stemming from the identified co-benefits? Is this value sufficient to make the energy efficiency investment viable?

Today's energy production facilities are either highly centralised (power plants) or highly decentralised (e.g. photovoltaic panels installed on roofs). What can learn from business models developed for transport (Uber) and internet (Google) that can integrate the multi-scale territorial perspective that characterises the diversity of actors and object in the area of energy efficiency, for example through smart grids.

EFFICACITY, the institute for energy transition in the urban environment, has been addressing these questions in a thematic program with the aim of delivering operational tools for use by stakeholders involved in urban projects (local authorities, energy and water suppliers, developers, etc.).

Following a literature review (part 2 of this article), a methodology for a broadened economic assessment was developed by EFFICACITY (presented in part 3). This methodology was applied in two urban projects

to test its validity, which is the subject of sections 4 and 5 of this article. We then end with a concluding section.

2. LITERATURE REVIEW

Environmental externalities have been studied in numerous projects and research articles and provide a solid basis to help identify broad families of externalities within the framework of an energy efficiency project (Amann, 2006), such as health impacts (Loftness et al., 2003), biodiversity protection (Ürge Vorsatz et al., 2009), and greenhouse gas reduction (IEA, 2014). In the case of environmental externalities, it should be noted that some States set "shadow values" that is to say, the value of the external costs when evaluating public infrastructure projects (Quinet 2008, Quinet 2013, CESD "socio-economic assessment" ...). The positive impact on local economic development (2014 Guennec et al IEA. 2009) or productivity (Loftness et al., 2003) are also revealed. This literature review has been synthesized in a reference book (Efficacy 2014) and an accompanying database (under development).

The following table provides some examples of the co-benefits of energy efficiency in the case of buildings.

Table 1. Examples of an integrated analysis of building functions and impacts (Source: Efficacy Externality reference tool and Nösperger & al., 2015)

Impact or externality category	Impact Description	Stakeholder
Health	Occupant health improvement thanks to comfort improvement	Occupier Occupying company
	Improved health thanks to facility (cycle boxes, shower facility, pedestrian paths...) allowing environment-friendly mobility (bicycling, walking)	Occupant
Productivity	Occupant wellness related productivity improvement thanks to comfort improvement (temperature, natural lighting)	Occupying company
	productivity improvement thanks to building-related positive corporate communication	Occupying company

Asset value improvement (“green value”)	Improved asset value (reduced vacancy period) due to advanced building indoor flexibility and adaptability	Owner
	Improved asset value due to reduced vacancy period or improved nominal rents thanks to advanced energy and environment labeling	Owner
Territorial economic development	New industry creation or reinforcement through the selection of technical solutions involving local firms	Local authority Local firms Inhabitants
Territorial facilities support	Building’s ability to store rainwater (avoiding the need for additional drainage facilities)	Territory
Potable water savings	Improved potable water using equipment which optimizes the sizing of the waste water treatment facility)	Territory
Emissions and pollution	Energy-related CO ₂ emissions due to comfort equipment such space heating	Occupier Territory World population

In fact, the main difficulty, when evaluating a well-defined energy efficiency project, lies in adapting locally these general externalities. While the enlarged economic evaluation of such urban energy efficiency projects can rely on proven methods (ISO 15686-5, Joumni 2009), or contrary to conventional evaluation methods such as Cost Benefit Analysis, where the State arbitrates between winners and losers, local energy efficiency projects require defining externality values which find endorsement by stakeholders for them to be then be inclined to contribute to a project on a voluntary basis.

The valuation of externalities is thus linked to the creation of economic models able to integrate those actors, traditionally absent or underrepresented, in current economic transactions around building projects.

In fact, beyond the business model, which is a monetary translation, the business model implies (du Tertre 2011 Nösperger et al, 2015.) gathering the following prerequisites:

- A basis for value creation and distribution (capturing) between the actors;
- The basis and formal structure of relationships between actors (contracts, formal or informal partnerships, "cooperative" society ...);

- Sources of mutual investment or financing operations;
- The nature of work performed by these players: skills, qualifications, activities produced independently or co-constructed (co-production).

The methodology presented in the next section proposes to address simultaneously the issue of externalities / co-benefits to consider and business models suited to their actual transformation into a monetary or non-monetary value.

3. METHODOLOGY

EFFICACITY developed an 8-stage methodology intended to assist in identifying relevant externalities of an Energy Efficiency project, determine relevant monetary values, and design suitable partnerships likely to convert them into economic flows (financial or non-financial):

Phase 1: Local context identification and definition of alternative solutions (stages 1-3):

- Step 1: Background and overview of the initial situation (nature of the project, scope) and identification of the sets of actors involved in the project.
- Step 2: Identification of technological and organizational solutions in energy efficiency adapted to the situation (and envisaged in the EFFICACITY relevant programs). Who do they concern and to what extent?
- Step 3: Classification and selection of a range of solutions

Phase 2: Externalities and benefits identification, selection and monetization (stages 4-6)

- Step 4: Identification and selection of externalities related to selected solutions.
- Step 5: Estimated market and non-market economic values
- Step 6: Arbitration of possible strategies to optimize resource allocation.

Phase 3: Identification of relevant partnerships/ contractual relationships and business model design (stages 7-8).

- Step 7: Design the business model adapted and sensitivity tests
- Step 8: Evaluation of the implementation conditions of the selected strategies: economic and contractual conclusions

4. 8-STEP METHOD APPLIED TO THE CONSTRUCTION OF AN URBAN BLOCK

4.1 Step 1: context

The planned urban block being subject to evaluation is located in a neighbourhood in the Paris basin shared with new buildings of a university campus, an architectural school, a Regional Express Railway station (RER), college halls of residence and a university canteen. This mixed urban block consists of 4000m² of offices and 13,500 m² student residences. The local authority is also considering building a large nautical centre (2000 m² Basin). The project is in an area with special status, a "new town", managed by a public development agency named EPA (Etablissement Public d'Amenagement).

EPA owns the grounds of the planned urban block and intends to sell it to the property developer who will commission and manage the project and supervise other contracted project managers such as for the halls of residence and the office buildings. This project is the subject of a single contract of Design-Build-Operate & Maintenance of which the incumbent manages the various components having already identified a number of subcontracting partners. EPA intends the cluster located in its district to be competitive internationally against other campuses.

Local energy resources include: an aquifer (120 m deep, 14° C), solar radiation, biomass (subject to demand by the local authority), and fatal heat from the nautical centre. A system composed of 5 wells was installed for the university building, with a discharge well back to the aquifer.

The energy balance of the territory points to:

- Net demand for heat from the student canteen in the campus, the building block and nautical centre. The net heat requirement of the building block is due to the predominance of residential housing (and high domestic hot water needs)
- Net cold requirements from the university building. This building will therefore significantly use a cooling tower before releasing water above or below the temperature of aquifer. However, the low flow rate of the aquifer will heat up the aquifer in the absence of additional uses for the waste heat.

4.2 Steps 2 & 3: Alternative energy solutions

The reference project, for calculating the additional cost of the energy efficiency solution, is a building block powered by a gas boiler and air-conditioning from adiabatic air coolers. The reference block is 30% more efficient than new period buildings.

The comparative analysis that follows, with respect to this reference solution, takes an energy efficient starting point (baseline).

In the context of this article, we will develop only the most promising alternatives, especially from the perspective of their intensity of use in a context of basically very efficient buildings. It is noteworthy that all of these alternatives include installing photovoltaic sensors whose production will be sold at a fixed feed-in tariff for 20 years.

The energy concept 1 of the building block is based on combining multiple sources of energy: gas, electricity, solar photovoltaic, and wastewater. Energy recovery from the grey waters is more robust (reliable and cost-effective) than solar thermal sources because it is simpler and requires no maintenance. Energy systems are centred on a thermorefrigeratingpump (TFP) that is not able to supply in a balanced way the hot and cold needs of the block. As a result there is a systematic loss of refrigo-calories (cold) having to be released back to the aquifer. This solution could be quite effective from a functional and energy standpoint in theory; unfortunately the temperature rise of the aquifer requires a search for alternatives. Indeed, while the energy balance of Bienvenue university building wells, on the one hand, and the building block V1 on the other (which are located at a distance) could compensate "partially", the very low flow rate of the aquifer does not allow this "compensation" to be effective.

The Energy Concept 2 relies on the Mutualisation of the abstraction from the aquifer. The thermorefrigeratingpump on this aquifer uses the same wells used for the university building. This solution has the advantage of partially addressing the problem of excess heat emitted annually into the aquifer by the Bienvenue Building (due to an overall cooling need for the year) that leads to its gradual warming (because of the low rate of flow of the aquifer preventing heat to disperse). The decision to adopt this solution is based on the assumption that coupling the university building and the building block is sufficient to balance the needs and reduce very significantly the heat discharge to the aquifer. The innovative character of

these buildings with high performance outer casings accentuates the risk of a mismatch between the simulated and observed behaviour. The coupled system “Building block – University building” may still be out of balance with an annual heat surplus, which would still contribute to the gradual warming of the aquifer.

The Energy Concept 3 relies on the Mutualisation of the abstraction from the aquifer and on the addition of a nautical leisure park.

The policy targets set by the local authority requires it to meet 50% of the heat demand of the nautical centre with renewable energy, in this case with solar thermal panels. The surface of these panels is downsized to avoid overheating.

Assuming that the “super-block” made of the projected building block and the university building to be in net heat excess in the summer (releasing water at 35° C), this balance could be used by the nautical centre to further reduce its summer minimal heat demand and consequently the surface needed for the solar panels. Before such considerations the surface area of the solar panel stood at 2900 m². Investment savings are therefore foreseeable.

4.3 Identifying externalities and co-benefits

We have to reason differentially (instead of reasoning on the comparison of absolute life cycle costs of each alternative) with respect to a high performance reference solution. The alternatives will not be compared with the baseline reference with respect to comfort, health, and mobility, which are independent of benefit from the mutualisation of the aquifer energy source. The real-estate value should also not be impacted. Most of the co-benefits discussed here therefore are focused on the impacts of the mutualised aquifer energy/cooling source. These are treated in Section 4.4.

4.4 Estimating the market and non-market values

4.4.1 Cost elements (tradeable goods and services)

The following table shows the cost elements related to the tradeable goods and services as compared with the reference solution.

Table 3: Financial results of the three concepts in relation to the reference (costs and market benefits)

	Extra investment	Impact on the yearly energy	Impact on annual	Electricity sales from solar

	costs	bill	maintenance costs	panels
Concept 1	+58€/m ²	-0.8€/m ²	+0.8€/m ²	-1.1€/m ²
Concept 2	+69€/m ²	-0.9€/m ²	+0.95€/m ²	-1.1€/m ²
Concept 3	+72€/m ²	-0.9€/m ²	+0.95€/m ²	-1.1€/m ²

4.4.2 Monetising non-market benefits

The previous financial balance must be completed with the assessment of monetized non-market benefits.

4.4.2.1 Fighting climate change

The following table shows the cost elements related to market goods and services, always by difference with the reference solution.

Table 3: Financial results of three concepts in relation to the reference (costs and market benefits)

	Gas Consumption (final energy)	Electricity consumption. (final energy)	Primary energy consumption	CO ₂ Emissions
Concept 1	-18.8 kWh/m ²	+4.6 kWh/m ²	-6.9 kWh/m ²	-3.7 kg/m ²
Concept 2	-22.7 kWh/m ²	+6.7 kWh/m ²	-5.4 kWh/m ²	-4.3 kg/m ²
Concept 3	-22.7 kWh/m ²	+6.7 kWh/m ²	-5.4 kWh/m ²	-4.3 kg/m ²

The three concepts outperform the reference in terms of GHG balance. This difference is greater for the concepts 2 and 3, with the reliance on the thermorefrigerationpump with a coefficient of performance (COP) greater than 3. We used the shadow price of carbon used in public investment evaluations (Quinet, 2013). This value is 52 € / t in 2015 with an escalation rate of 4.5%, equivalent to the discount rate used in public investments under the law of Hotelling (Quinet, op.cit.).

4.4.2.2 Environment, biodiversity and semiotics

While the project global warming attenuation capacity is indisputable, there may be an impact on biodiversity and the natural environment from the warming of the aquifer. Without corrective action, because of Darcy's

velocity (flow rate) of the aquifer and hardness of the water, we could expect this warming over 15 years to result in two consequences:

- The development of algae and amoebae,
- Blockage and instability of the release well from the thermorefrigerating pump at the university building (already installed). The use of cooling towers in the university building slows the phenomenon but does not suppress it.

Preventing the warming up of the aquifer improves the overall robustness of the system (at a 15 year horizon). The alternatives (concepts 2 and 3) for mutualising and compensating the heating and cooling needs reduce the warming of the aquifer. Furthermore, each alternative would give the territory a "showcase" of an innovative university campus, and fulfil the ambition of international renown mentioned above given the university's focus on energy transition and sustainable development. However, this effect is much more significant in the case which includes the water leisure park (concept 3).

The monetization of impacts related to the aquifer was carried out by the method of costs of damage (Pearce et al., 2006). The main physical consequence is the impossibility of using a geothermal heat pump for the university building at a 15-year horizon. The assessment of that damage may be based on the discounted residual value of the equipment, valued at € 24 / m² (relative to the surface area of the planned building block) prior to discounting. The discounted value will be chosen to monetize the efforts for preventing the warming of the aquifer in the case of concepts 2 and 3.

In addition, EPA announced it would cover 50% of the investment cost associated with these three concepts in recognition of its innovative nature and international renown.

4.4.2.3 Operating savings of the university building

The expected synergies between the building block and the university building should reduce the release of cold effluent into the aquifer, enabling both improved energy efficiency of the cooling towers of the Bienvenue building and decrease the use intensity. Thus, it is predicted that the overall operation of these towers is expected to fall between 20-60%!

This is accompanied by reduced maintenance and operating costs and longer service life of the equipment, a notable reduction of the operating costs. This represents an externality to the extent that it constitutes a cost or a benefit to either party, without it being valued economically. This externality is positive as the action of agent A (the use of the aquifer by the building block) results in improved well-being of another, agent B (a

decrease in operating costs of the university building) without the latter having had to pay the price (Efficacy 2015).

In the absence of a partnership linking the two parties, the university building is outside the economic reasoning of the actors of the building block.

Based on the information provided, the operational savings from the cooling towers permitted by mutualisation between the university building and the building block (concepts 2 and 3) were estimated at € 0.1 / m² (based on the surface area of the planned building block).

4.4.2.4 Solar panel investment savings for the nautical centre

By broadening the mutualisation to include the nautical centre the synergies allow a reduction in the surface area of the solar thermal panels (see above) of approximately 10%.

As above, this benefit may be associated with an externality. Based on the information provided, 10% investment savings in solar panels represents € 180,000, or 10.3 € / m² (based on the surface of the building block).

4.5 Step 6: Arbitration of the strategies for optimising the allocation of resources

The table below shows the results of the evaluation in overall cost and extensive global cost (ISO 15686-5) of the different variants relative to the reference solution, performed over a period of 20 years with a discount rate of 3% (as per the EN 16627 standard). A negative value indicates a gain relative to the reference solution.

Table 4: Calculation of total cost (simple and extended) of the different concepts (€ / m²)

	Additional investment costs	Impact on annual energy costs	Impact on annual maintenance costs
Initial investment	58.0	69.0	72.0
Operating costs for energy and water	-10.9	-12.4	-12.4
Maintenance costs	11.5	13.1	13.5
Residual value for subtraction	-1.7	-2.0	-2.1
Social costs CO ₂ /period	-4.2	-4.9	-4.9

Production PV	-15.7	-15.7	-15.7
Benefits related to the operating savings for Bienvenüe building	0.0	-1.5	-1.5
Investment savings for the nautical centre	0.0	0.0	-8,7
Environment and semiotic benefits	-28.2	-42.7	-44.7
Extended evaluation	8.9	2.9	-4.5

It appears that the energy savings will not even cover the additional maintenance costs and the competitiveness of all three concepts depends on the value of the external effects. However, at a 20-year horizon, only e Concept 3 is economically competitive with respect to the reference solution. Choosing this path requires to engage in negotiations involving numerous partnerships.

4.5.1 Step 7 and 8: Designing of an appropriate economic model and Evaluation of the deployment of the selected strategies

Up to Step 6, we were in a cost/benefit logic proceeding by an itemised accounting (costs / market and non-market benefits). It must be formalised by the development of relevant partnerships following a logic of contributing actors and economic flows from one actor to another.

Partnerships can be bi-lateral or multilateral (for instance in the case of a "mutual fund" drawing contributions for different benefits or to supervise the bilateral exchanges). There's an apparent need for "systems of rules that bind the actors together, and are developed and adopted during the project" (Pasquelin, 2015). Beyond this governance, the success of such an economic model hinges on genuine cooperation between actors, who share an interest in each other's activities and how they interaction towards achieving a common goal (du Tertre, 2013). This instance illustrates, within acceptable technical and economic conditions, the possibility for an assembly comprising the three parties (the university building, the building block and the nautical centre) in the context of a shared willingness to showcase the exemplarity of the project.

5. THE METHOD IN THE CASE OF A DISTRICT HEATING NETWORK

The second application of this methodology was carried out on a district heating project (steam provided by an incineration plant). The sensitivity analysis of the sector-specific economic models (taking into account identified externalities) has been carried out for each actor's decisions. The two scenarios under study are the retrofitting of building to make them energy efficient, and the application of household waste minimisation policies. The externalities associated with these policies leads us to imagine new configurations of player games that redistribute earnings (profits) and losses for the most beneficial outcome. This constitutes a new way to build an all-encompassing cost approach by establishing new contract arrangement.

5.1 Scenarios and simulations

We are interested in all the actors' up- and down-stream of the two scenarios:

- Users of the heating network (households) recipients of the final energy bill and its share of domestic income;
- The incineration plant as heat supplier, and the contribution of heat sales to its operating margin (net of investments);
- The operator of the district heating system, who adapts the billing of its domestic customers according to the energy source and thus maintains its operating margin.

Three parameters are modified independently and simultaneously to develop various scenarios and assess the economic effects associated with the choice of its actors. These three parameters are:

- The percentage of waste incineration: today several local policies target waste minimisation preferring to maximize recycling to the detriment of incineration.
- The percentage of the renovated buildings on the district heating network: building standards improve efficiency and reduce energy consumption. The renovation policy targets a blanket application of new building standards.
- The percentage of residential housing connected to the district heating network. Recent policy orientations, national and local, have made heating network a key policy tool for attaining energy transition objectives.

5.2 Results

The fall in volumes of waste incinerated expected from waste minimisation policies may impact significantly the earning of partner stakeholders in a district heating network. The first concerned is the operator of the incineration plant, who sells less heat and therefore reduces its earnings. The plant operator must compensate by increasing prices to be able to purchase an alternative source of energy (gas) and fulfil its contractual obligations with downstream users of the district heating network. Beyond a certain threshold of waste reduction the operator of the heating network must install a booster station, increasing its operating costs. Its margin is decreased but is not erased, since it passes most of the additional cost to its users.

5.3 Arrangement of players games

The resilience of the heating network needs rethinking, without compromising either the environmental or economic objectives pursued in the two policies.

In the case of a fall in the volume of waste incinerated, it seems more difficult to remove the losses for all players, but still we can try to maintain the profitability of the system. In such a case, and to maintain a satisfactory level of renewable energy in the energy mix of the network, the thermal renovation of buildings should be encouraged (assuming it will reduce use and cost of fossil fuels to users). However, such action does not compensate the losses for the heating network and incineration plants. We can, in this case imagine a mutually beneficial compromise to encourage thermal renovation for users and to compensate the district heating operator and incinerator for the loss of business (including downsizing the furnaces to reduce operating costs).

The reduction in waste is not necessarily negative for the system; it is possible to "downsize", through public financing, all elements of the chain. The decrease in the production of household waste results in lower operating costs for the community. These savings could be redirected to finance this upgrade, and then proceed with a gradual decrease in user-fees for managing household waste.

The scenarios with variations of multiple parameters showed that:

- It is possible to compensate for the effects of one of the parameters by those of the other.

- We need to rethink about how to define the energy strategy of the urban area in an integrated way: you have to consider actions on consumption, production and distribution simultaneously. A player should have the supervisory role in planning and upholding the general interest.

6. CONCLUSION

The application of this methodology turns out to be effective for identifying and valuing externalities. A key point is the building of new economic models able to convert the identified economic value into financial flows (or equivalent) between stakeholders. These models will rely on a formal basis (innovative partnership, contracting) but especially on informal ties (trust between actors, organizational relevance...). The development of relevant formal and informal resources can be delegated to a trusted third-party. To help the latter achieve this complex work, operational tools still need to be developed. These may include:

- a comprehensive reference document covering externalities (literature-based review) to assist in the complex dialogue between stakeholders on the value of externalities;
- a global life-cycle costing calculation tool including externalities valuation;
- interviews, support guides for the negotiation between stakeholders (benefiting from positive externalities) and who have the willingness to contribute to the project in order to ensure that it become viable;
- specific contracting and partnership supporting tools in the areas of building renovation and district heating.

The development of such tools is the main objective being pursued by Efficacy in the framework of this project.

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