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Emerging costs deriving from blackouts for individual firms: evidence from an Italian case study

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Among the costs deriving to firms from electric blackouts, emerging costs are the less studied ones. This work aims at shedding some light on the specific topic with an empirical approach. It performs in fact three case studies, describing blackout emerging costs for three firms of very different industries. Data obtained in the cases are described, and a cost function is tentatively sketched. Case studies show that emerging costs, though not prevailing in value over the lost production costs, may be relevant in some cases. At the end of the work, conclusions are drawn, and learned lessons are outlined.

KEYWORDS: electric power; blackout; emerging costs; case studies; production loss.

JEL CODES: D24; D61; L94.

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Contents

Introduction [1]

Electric power blackouts are one relevant issue that contemporary society must deal with. In fact, their negative impact can be relevant under several points of view. Daily life and economy are strongly affected by sudden power blackouts: it is because of this that several systems are implemented to avoid their insurgence. Consequences of blackouts can be for instance disruption of infrastructures or stop of the production systems. Moreover, they can involve the impossibility to supply essential services such as communication (both physical and telematics), health care or transportation. Finally, the home life of individuals can be also affected, since nowadays most domestic activities rely on electricity.

Thought households, firms, governments and society in general are aware of the importance of the blackouts consequences, the common perception tends to underestimate the connected risk, above all in countries enjoying an efficient electricity system, for the lack of direct experience. Maybe also for this reason, the knowledge of the quantitative value of such damages is very limited and estimates vary relevantly depending on the adopted methodology and on the cost categories included in the evaluation.

With focus on the productive sector only (firms), it is evident that a primary source of damage is linked to lost production, since nowadays most production processes depend on electricity. However, blackouts can often generate emerging costs directly caused by their insurgence. That is, blackout costs may derive not only from the loss of production during black-out time, but from other causes like breakage of machinery and infrastructures, long reactivation procedures after blackout or after more serious damages, or from waste of materials due to the stop of production lines (above all in processed where an high or low temperature is involved). Breakage and reactivation costs are in turn ascribable either to

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[1] This work is based on the research activities carried out in the context of Essence, *Emerging Security Standards to the EU power Network controls and other Critical Equipment, a* project financed under the programme "Prevention, preparedness and consequence management of terrorism and other security-related risks" HOME/2011/CIPS/AG. For more detailed reference see Calabrese, Finardi and Ragazzi (2014) and Ragazzi and Garcia Gutierrez (2015). All project output can be downloaded at http://essence.ceris.cnr.it/

materials or personnel costs, or also to a loss of production due not solely to the instantaneous effects of blackout, but also to its extension over time.

The choice of the degree of detail in evaluating the cost of blackouts depends heavily on the purposes of the analysis. An approach including only lost production (straightforward and cheap to implement) can be sufficient for an analysis aimed to have a rough idea of the order of magnitude of the damage (which is often the case for general policy studies) (see for instance Bruno *et al.*, 2014; De Nooij et al., 2007; Leahy and Tol, 2011: Linares and Rey, 2013). However, when a higher level of precision is needed, for instance when policy makers need to identify which sectors are more sensitive to interruptions, including the total value of the emerging costs is of crucial importance. Moreover, an even deeper detail is necessary to produce a valuable analysis from a managerial perspective (for example to evaluate the opportunity to invest in back-up facilities). Indeed, in this case it is important to disentangle the total value of the emerging costs in its main components, which can be very different across sectors, and to understand its relationship with blackout duration, which is likely to be functionally complex. Finally, separating lost production (and lost profit) from actual emerging cost could be very important from a legal perspective, producing a reliable basis to rely on in case of litigation for damage compensation claims.

The aim of this study is to shed light on the particular topic of emerging costs deriving from blackouts, starting the analysis from specific firms having a production process that might, in principle, be heavily affected by the sudden lack of electric power. In fact, the specific topic discussed in this work is still underexplored in scientific literature to the best of our knowledge. Far from providing an exhaustive picture and quantification of all the possible sources of damage in case of electric interruption, this work demonstrates, at least qualitatively, that emerging costs are a relevant component of the total blackout damage, and represents a useful starting point for future research aimed at providing a more rigorous identification of the nature and magnitude of this source of inconvenience.

Another strength of the present work lies in its relation with the below described methodologies based on surveys. A survey approach, with respect to the productive sectors, is quite difficult to develop and very costly in terms of resources and time. Moreover, in most cases, existing works highlighted very low response rates. For instance, in valuable contributions such as Reichl et al. (2013 a, b), the authors highlight that, after having sent a presentation of their questionnaire and an invitation to participate to more than 100,000 non-household consumers, only 201 of them participated in the survey. This is probably due to the fact that, in spite of their importance in any production process, the exact quantification of the damages from blackouts is a point rarely considered by firms.

Moreover, often the related costs are not accounted for separately. Filling a questionnaire on this topic, therefore, can result in a rather demanding task. If, on one hand, the expected response rate would be low, on the other hand determining the value of emerging costs for a set of industry or a geographic area, or even for a single industry, requires a large amount of information, due to the enormous variety of situations.

In this sense, a preparatory activity aimed at recognizing and selecting the potential damage sources, the differences among sectors and among organizational structures is of crucial importance for developing any further survey activity. Thus, our contribution can be considered as a preparatory study for the development of a subsequent survey-based work.

Finally, a further advantage of our approach (which exploits the fact that we are working, in this phase, with limited quantity of data) is the openness of our interviews.

Rather than following a predetermined standard trace, we have fixed *a priori* only some basic questions, allowing the interviewees to highlight and deepen the description of the more relevant blackout effects from their firm's viewpoint. This gave us the possibility to extend the range of potential damage we were considering.

As above described, costs deriving from electricity interruptions are of different nature, and – besides loss of consumption goods – might be due to breakage of machinery, or costs for reactivation of lines up to serious damages making production lines useless beyond any repair. Finally, as we will discuss later on, it emerges the relevance of non-material damages in terms of reputation linked to the impossibility to meet delivery deadlines.

The rest of the paper is organized as follows: section 2 contains the theoretical framework, discussing past literature on the topics of evaluation of blackout costs and of emerging costs. Section 3 presents some hints on the methodology followed, while section 4 contains the core of the paper: the three case studies are outlined. Finally section 5 contains the discussion of results and the conclusions.

1. Theoretical framework

In order to theoretically frame this work, past literature on the evaluation of blackout costs is discussed. Blackout cost evaluation is a complex issue.

As the following will show, literature presents to the best of our knowledge a substantial lack of analysis on the specific topic of the study of emerging costs, and in particular of those deriving from electric blackout. Thus we must refer to a more general set of literature to frame the present effort.

The economic literature has developed several methods to infer the cost of electricity interruptions. De Nooij et al. (2007) provide a taxonomy, which we follow in order to organize some of the most relevant contributions to the topic.

A first approach is the so-called *Production function approach*, which estimates the damages from interruptions in terms of lost production (non-households) or lost leisure time (households) (see De Nooij et al., 2007; Leahy and Tol, 2011; Praktiknjo et al., 2011; Linares and Rey, 2013).

The damage is proportionally related to the lost energy, since the underlying assumption is that no productive activity is possible in absence of electricity (in the same vein, leisure time cannot be enjoyed in case of electricity interruptions).

This methodology has been among the first ones employed in blackout cost evaluation, at least in its simplest formulation, which *approximated*[2] the total damage using the unitary damage values computed as ratio between GDP and energy consumption. Even in more refined applications (e.g. differentiating the unitary damage by sector, or relying on input-output matrices), the *proxy* character persists, since factors such as restarting times, damages to equipment or non-complete energy dependence are neglected. It must be noted that the present contribution tries to fill – at least partly – this gap. However, this method presents advantages in terms of application, which is straightforward, and limited requirements in terms of data, since the necessary macro-economic data on production and energy consumption are often publicly available.

A second approach, followed in the past to analyse blackout costs, is that of *Revealed preference methods*, based on market behaviour (Caves et al., 1992). These methods have the desirable property of relying on real market choices of electricity consumers in order to infer the value of supply continuity. Examples of observable market choices that can be exploited in this sense are the purchase of backup facilities or the use of interruptible contracts. This approach has the appealing feature of relying on actual behaviour. Nevertheless, the options are often available for few users categories (e.g. large users), while no information would be provided with respect to the other segments.

Another approach is that of the analysis of *case studies related to specific events* (Sierra and Fierro, 1997; Anderson et al., 2007). The common feature of this set of approaches is the presence of a real blackout. In some cases, the consequences of the blackout can be listed and monetized, in other works a survey can be carried out immediately after the event. The main desirable property of this method is that it allows to evaluate the consequences of a real event, or at least that the temporal proximity of a real event increases the consumers awareness about the actual value of the service. However, there is only limited possibility of generalizing or extending the evaluation to events with different characteristics.

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[2] That is the reason why the approach is said to belong to the category of "proxy methods".

Among the approaches based on *surveys*, finally, we must mention the *Stated preferences methods*. Differently from the previous methodology, here the considered blackouts are, in general, purely hypothetical. Interviewed people are asked to state a value for blackouts. Initially the idea was just to ask the interviewees to quantify the cost or the inconvenience linked to outages. More advanced approaches are aimed to elicit the value respondents assign to supply continuity either in terms of amount they would pay to avoid or reduce the interruption (willingness to pay - WTP) or in terms of amount they would like to receive as a compensation for an increase in interruptions (willingness to accept – WTA) (see for instance Beenstock et al., 1998; Carlsson and Martinsson, 2008). They can also be asked to choose among given combinations of interruption characteristics and monetary values. This method is useful especially for measuring the damage at individual or household level, where the preference structure plays a major role. The main drawback is related to the fact that this approach can be prone to different types of bias of cognitive source; in particular, the way questions are asked can have an important impact.

Finally, it must be noted that the different approaches are not mutually exclusive: Reichl et al. (2013a, b) employ the stated preference approach for households and a method based on the production function enriched with information collected through firms' surveys for the productive sectors.

It is worthwhile to point out, now, that the mentioned methodologies, except the production function approach, account, at least implicitly, for the emerging cost problem. Indeed, in revealed preference methods and in works applying the WTP and WTA approaches, the respondents, making their actual or hypothetical choices, consider not only the lost production, but also all the other possible sources of damage. Also in other survey based studies (Balducci et al., 2002; La Commare and Eto, 2006; Bertazzi et al., 2005), where respondents are explicitly asked to state their interruption cost, these sources of damages are accounted for, with different degree of detail. Finally, in Reichl *et al.* (2013a, b), comprehensive sector specific damage shares are estimated, in terms of proportion of daily value added lost.

What is still missing in the literature is a sector-specific quantification of the emerging costs expressed as a function of the interruption duration, broadly recognised as the primary cost driver (Ghajar and Billinton, 2006). Indeed, some of the mentioned studies recognize that not only the total damage is function of the duration, but also that this relationship is highly non-linear (see also Caves et al., 1990, on this point). Such non-linearity is mainly linked to the presence of emerging costs, which often occur after fixed duration thresholds, which differ relevantly across industries and organizational structures. Finally, in general the existing literature focuses on total damage value, not separating the different elements of lost production and emerging cost, which can be interesting from the legal point of view.

2. Methodology

The chosen methodology entails the deepening of some cases via interviews, aiming at assessing both the nature of the costs and their values. The economic quantification, in this sense, is particularly complex since it involves to determine costs which are rarely accounted for separately. The three proposed case studies, therefore, differ in the level of depth of information. Nevertheless, we believe they will provide important insights on the variety and the importance of possible additional sources of damage.

The chosen case studies are the following ones:

• Sandwich insulating panels;
• Cement producer;
• Fresh milk producer.

These three cases have been considered interesting for the present study, not only because the firms belong to very different sectors, but also because the main component of emerging cost comes from different sources. We will highlight that, in the first case, the damage to the equipment plays a major role, while the cement producer is more concerned with the issue of very long re-starting times. Finally,

in fresh milk production even a short blackout during the treatment causes the loss of the milk, clearly a perishable raw material. Finally, also the organization of production matters, since we find that the largest management complication arise when the firms operate "Just-in-time".

3. Case studies

3.1 Sandwich insulating panels

This case study is relative to a medium firm located in North-western Italy. This firm produces insulating panels using a continuous process. Their production can be in principle "24/7" and is thus an ideal subject for this analysis. Moreover the production of panels exploits the use, as raw materials, of metallic external layers coupled with fillings made of an expanding polymer. Thus a sudden stop of production causes the stop of the external layers inside the line, and the simultaneous uncontrolled expansion of the filling polymer. This in turn makes the restarting of the line, once the blackout has finished, rather complex and time and personnel-consuming. In fact the production line has to be completely cleaned, wiping off the expanded polymer, and part of the metallic raw material must be forcedly discarded. Moreover the machinery present in the production line contains electronic parts that are sensible to transient overvoltage. Thus, given this fact, breakage of such parts may occur, and has actually occurred in the past.

Thanks to the full collaboration of the company's owner, it has been possible to obtain accurate data on the costs of all the different emerging costs items. Thus it has been possible to estimate the reactivation costs, the costs deriving from damages to the line and, finally, the costs of waste due to the sudden stop of the production line. It is also relevant that the firm has been able to retrieve real cost for damages incurred in previous blackouts. Though the firm endowed itself of a set of Uninterruptible Power Supplies (UPS) units able to assure continuity for short blackouts, breakage due to sudden power changes occurred anyway.
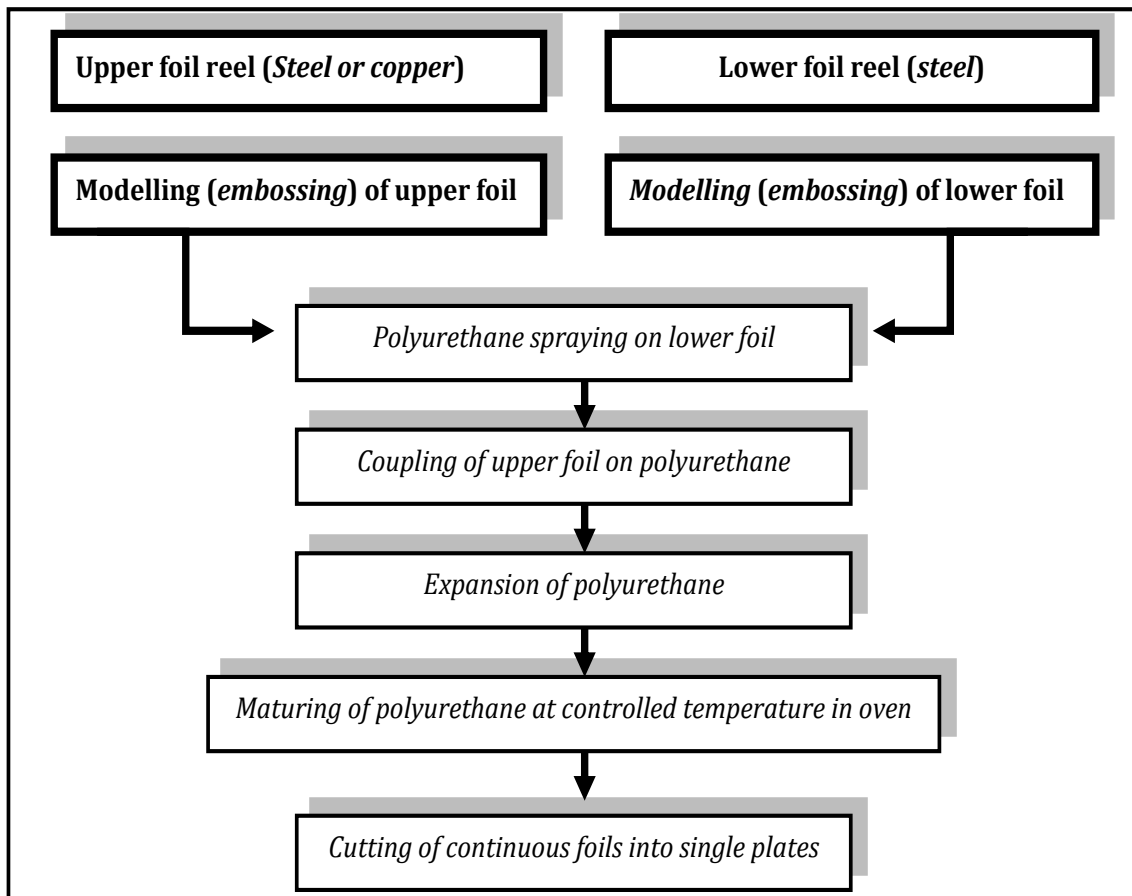
Upper foil reel (*Steel or copper*)	Lower foil reel (*steel*)
Modelling (*embossing*) of upper foil	*Modelling (embossing) of lower foil*

Polyurethane spraying on lower foil

Coupling of upper foil on polyurethane

Expansion of polyurethane

Maturing of polyurethane at controlled temperature in oven

Cutting of continuous foils into single plates

Figure 1: Insulating panels: Scheme of production process

The NACE/ATECO 2007 code of the firm is 251100 (building of metallic structures and assembled parts of structures). Its turnover (revenues from sales and services) for 2012 has been of about € 55Millions. It employs currently 67 employees. As above described its core business is the production of sandwich insulating panels. Such panels are produced creating two ad-hoc shaped metallic foils, and subsequently injecting polyurethane foam between the two foils. The foam ensures both thermal and acoustic insulation. Alternatively the filling can be made of rock wool. The production process is performed in continuum. In the plant several production lines are present. Three lines produce polyurethane-filled panels and two lines rock wool filled ones. All the lines might theoretically work in a 24/7 continuum cycle. In practice production suffers high variability, because its main customer industry – building – has a high seasonal cycle. Production flow depends quite heavily on the period of the year also because the time–to-market is

very short. In order to reduce storage costs, production is almost "just-in-time"; in some cases produced panels are directly loaded onto trucks and sent to the building site where they are installed. This fact underlines that a stop in production due to black-outs may in some periods generate huge problems in terms of customer satisfaction or reputation. In order to assess emerging costs due to blackouts, several components must be taken in consideration.

The first one depends on the production technology, and applies only to polyurethane-filled panels' production. This is the cost of cleaning and reactivating of lines. It is due to the fact that polyurethane, once sprayed on the metallic foil that should enclose it, continues expanding with time.

Thus, if it is not contained between the two metallic foils, continues expanding, and eventually fills the working space of the production line. Thus, after the end of the blackout, a certain amount of time and effort of workforce is needed to clean the workspace of the line. This does not happen for the production lines working with rock wool filling.

The second component applies to the whole production plant, and is due to the search-and-retrieval and subsequent repair of damages due to the blackout itself.

The third and last component again applies to polyurethane-filled panels' production. This component is the cost of waste, and is due to the meters of panel that are damaged by the expansion of polyurethane and have to be thrown away. The number of meters depends in turn on the speed of production (meters per minute) of continuum lines. This is dependent on the type of product.

Finally, it must be noted that the firm has acquired a park of batteries able to supply to short blackouts (lasting up to tenths of second) for all the production plant, at a total cost of about € 80,000. About the nature of the costs that are described below, it must be pointed out – before describing the cost equation – the nature of the single cost entries in terms of their characteristics of fixed/semifixed/variable costs. The three components are variable, as their value basically depends on the number of production lines at work at the moment of the blackout, N_L. Nevertheless at the end of the case study an average value of N_L. (mediated over yearly productivity) has been estimated.

From the above reported description the following cost equation can be defined:

Black-out cost function (B_{CF});

$$B_{CF} = R_C + D_C + W_C$$

That is, reactivation costs, damage costs, waste costs, where in turn:

$$R_C = 5 \times (2H_C) \times N_L$$

5 = number of persons working on a single line;

2 = number of hours needed to clean up the line;

H_C = personnel hourly cost ≈ 18 €;

N_L = number of involved production lines = 1 to 3 (mainly depending on timing and season of the black-out)

$$D_C = K_1 \times [(K_2 \times H_C) + B_C + (K_3 \times 5 \times H_C \times N_L)]$$

K_1 = constant, probability of a damage caused by black-outs;

K_2 = constant, number of man/hour needed for searching and repairing the damage;

K_3 = constant, number of hours of inactivity of the personnel (5) working on the line due to search and repairing of damages;

H_C = personnel hourly cost ≈ 18 €;

B_C = cost of repairing (materials and spare parts);

N_L = number of involved production lines = 1 to 3 (mainly depending on timing and season of black-out);

$$W_C = n \times M_c \times N_L$$

n = waste meters of linear production (usually 8 – 10 m);

M_C = cost of a meter of product;

N_L = number of involved production lines;

K_1, K_2, K_3, B_C and M_C have been estimated out of the effective costs of the last occurred blackouts.

For what about the assessment of K_1, the four 2013 blackouts resulted in three damages to the electric equipment of the firm. Thus K_1 could be estimated as ≈ 75 % (0.75)[3].

Again according to 2013 data, K_2 should be estimated in about 4 hours and 2 persons, total 8 man/hours, and B_C as about € 1200 (the cost of 4 electronic boards, costing € 290-330 each). Accordingly K_3 is four hours.

Finally, about W_C, for each blackout 8-10 meters of panel should be discarded for each line. The average price at sale of panels is 15 €/meter (averaged over the total yearly production).

Assessing N_L is more tricky, as this value (between 1 and 3) depends on the period of the year (late spring - beginning of summer is the period when production peaks). It can be considered in the following assessment of production loss, which completes the above emerging cost equation.

An estimate of the maximum possible production gives us the value of 6,082,000 meters of panels per year. This is obtained as follows:

Average production = 8 m/min (average speed of production line) = 480 m/h = 3480 m/shift (8 hours) = 11,520 m/day.

Daily production = 3 (lines) * Average production = 34,560 m/day.

Daily production * 220 (working days in a year) * 0.8 (efficiency) $\approx 6,082,000$ m/year = Y_P.

The real production is of course lower than productive capacity, and is about 4,250,000 meters/year = R_P. As the total number of hours per year is equal to 24 hours x 220 working days/year x 3 lines = 15,840 hours, the average (on yearly basis) production per hour per line is about 268 meters. Thus, given the above

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[3] This estimation is obviously only tentative, as the statistical basis for this calculation is rather restrained. Nevertheless past anedoctal evidence (which had not been recorded but which was reported during the interviews) supports the fact that probability of faults is not null and can be estimated with reliability around this value.

average (over the total production) price at sale of 15 €/meter the average loss of production for an hour of blackout is roughly € 4,024 per hour blackout.

Given the above values, we can estimate $N_L = R_P/Y_P *3 = 0.699 * 3 = 2.096$

Thus we calculate $B_{CF} = R_C + D_C + W_C$: € 377 + € 1573 + € 251 ≈ € 2,200

This value is averaged over the yearly productivity. If we want to deal with the maximum costs of specific blackouts, then the number of production lines N_L must be considered in three separate cases. Then, summing up, B_{CF} is equal to:

$$B_{CF} = (5 * 2 * 18 * N_L) + ((8 * 18) + 1200 + (4 * 5 * 18 * N_L))) + (10 * 15 * N_L) =$$
$$= 180 * N_L + (1344 + 360 * N_L) + 150 * N_L;$$

Table 1 contains the costs for each component and each of the three cases, as well as the totals. In the above reported equation and in the table the value of K_1 is obviously 1, as in this case we are not dealing with the average blackout but with the maximum costs of specific blackouts. The last line in the table contains the full value of lost production for the three cases. This is calculated simply multiplying the average value of linear meter of product (€ 15) times the full productivity of each line (480 m/hours) not taking in account any correction (efficiency, average yearly production, etc.). It is easily seen that, although B_{FC} should not be considered as irrelevant, the costs deriving from loss of production become quickly (after about half an hour's blackout) predominant. In fact the blackout cost B_{CF} is not time dependent, as the damage is produced within minutes (or even seconds in case of the component D_C) from the blackout.

Table 1 – costs in € for each case

	$N_L = 1$	$N_L = 2$	$N_L = 3$
R_C	180	360	540
D_C	1,704	2,064	2,424
W_C	150	300	450
TOTAL	2,034	2,724	3,414
Loss of production	7,200	14,400	21,600

The presence of the battery backup system actually allows the continuity of production for shorter blackouts, which can more easily occur. Nevertheless in case of serious and prolonged blackouts the backup system is obviously not effective.

3.2 Cement producer

The focus of this case study is a company operating in the production of cement, concrete and construction aggregates. Although the group is large and operates worldwide, our case involves the operations of a relatively small plant, mainly involved in the grinding and distribution phases of the production chain. This small plant employs 50 workers, 10 of which are devoted to R&D activities. It has a productive capacity of 700,000 Tons per year. At present it is operated at a saturation level of about 60% of its capacity, also due to the general economic crisis, which had relevant impact on the civil engineering and building industry.

The production process is continuous and the activity is organized in three work shifts, while the distribution-related activities are not continuous and involve two work shifts.
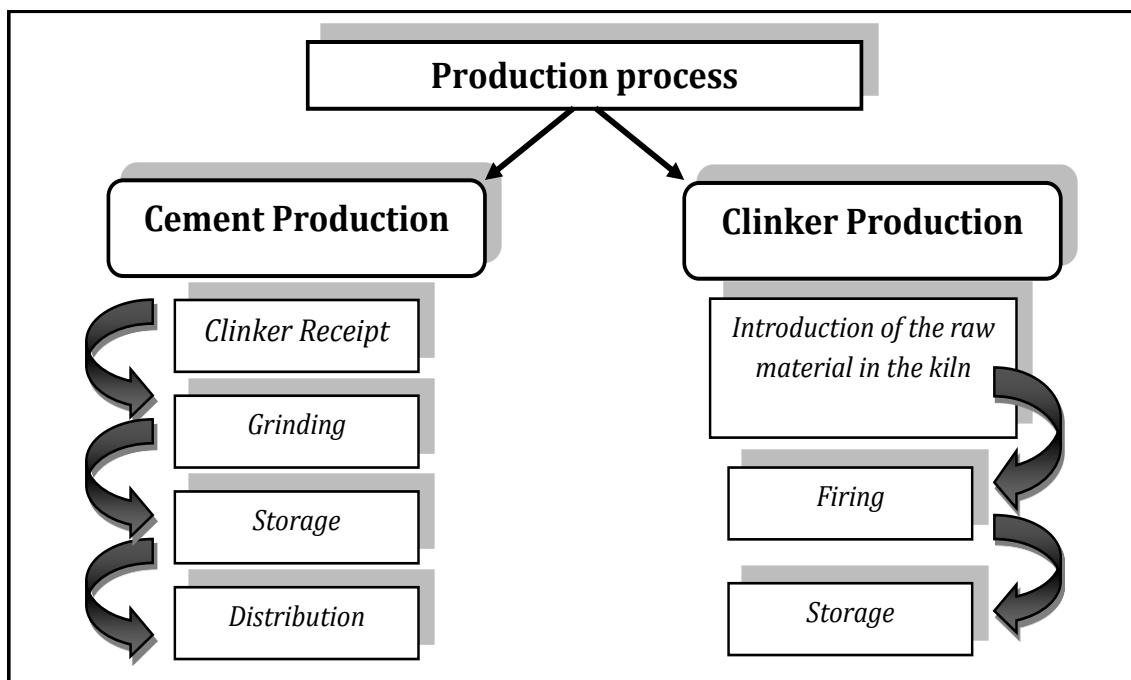

Figure 2 – Cement production process

The plants receives the clinker (the main raw material) daily and transforms it into cement employing grinding processes involving one or more mills, with the addition of other components. The factory produces 5-6 different types of cement.

The product is then stored in silos and later distributed to the customers, either unpackaged or bagged. Although grinding is the core activity of the plant, it has recently been involved in the production of a particular kind of clinker. Indeed, the plant owns also a small cement kiln, employed for this purpose with a capacity of about 150 tons per day[4].

The whole process is highly electricity dependent: this source of energy is necessary for most activities, including material transfer, mills and machinery, operation and rotation of the tubes of the cement kiln. Moreover, all the electronic supports to the production need a continuous and stable supply of electricity.

Nevertheless, the factory has subscribed an interruptible service contract (2 MW, covering the average power employed by the whole plant), which has been considered highly convenient from an economic perspective, although it requires relevant investments for the firm (for instance in term of UPS, generators and reset procedures). This fact allows a more easy evaluation of the consequences of an interruption, bearing in mind some relevant points.

First, it is important to notice that the effects of an interruption in electricity supply differ relevantly, depending on the time of the day the blackout occurs at. Indeed, the most energy-consuming activities are carried out mainly during the night, in order to enjoy more favourable electricity tariffs, while other activities (e.g. related to product packaging and distribution) are more concentrated during the day. Second, statistically, the interruption related to the interruptible service contract are in general very short (few minutes), but the re-starting time is relevant. An interruption of 3-4 minutes implies about 1 hour to re-start operations, since all the reset activities have to be carried out manually.

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[4] To give a rough idea of the plant dimension, we must consider that a "large" kiln can produce 5000 tons per day

In general, the first effect of an interruption is a stop in production; quite obviously, the longer the interruption, the larger the amount of lost production. Globally, we can say that an interruption generates losses in production proportional to the interruption duration, plus a fixed re-starting time of one hour. This fact is not likely to generate problems in terms of customer satisfaction or reputation (except for long durations in periods of high demand or in case of particular orders), since the process is mainly oriented to produce warehouse. However, from the mechanical point of view, some problems can occur to the equipment (e.g. mills) in terms of blockage or obstruction, since the physiological operation procedure do not foresee production breaks when the machinery is full. This fact would require maintenance interventions. Damages to the electric equipment are also likely, although the direct link with interruption is not evident or easily demonstrable.

Electronic equipment is very sensitive to interruptions and transient overvoltage, and protected by UPS in order to avoid damages and data losses. These back-up facilities are effective for short-medium blackout durations. If the duration is relevant (5-6 hours) the UPS support could not be sufficient.

The most delicate process relates to the firing activity. The kiln operates at very high temperatures (1300°-1400°), and natural gas is the main fuel. In case of interruption in the electricity supply, a generator[5] allows to maintain a slow activity of the kiln: a sudden block, at such a high temperature, could bend the tube of the kiln itself. For the same reason, the temperature must be reduced. Therefore, once the service is restored, the kiln must be heated again, and the operation requires time and a relevant amount of natural gas. Also in this case, the longer the interruption, the broader the temperature fall, and so the higher the cost of re-heating, which can be roughly estimated in the range of 500 – 1000 €. Finally, the material present in the kiln can undergo only small temperature falls (about 20°). Larger variations make the product not suitable for sale. It can only be recycled in

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[5] The generator for the kiln and the UPS are the only back-up facility present in the factory.

small proportions (5-10%) as input. An interruption, therefore, generates about 7-8 tons of product to be recycled[6].

3.3 Milk producer

The object of this case study is a dairy firm located in the North of Italy, employing about 50 workers. The prevailing capital share belongs to small-sized milk producers located in the surrounding area, which also provide most of the treated raw material. The firm supplies customers and distributors located in Northern and Central Italy.

The operations involve two main activity branches: the first one relates to the treatment, packaging and delivery of fresh milk and cream, while the second one is mainly related to storage and distribution of other dairy products, not internally manufactured.
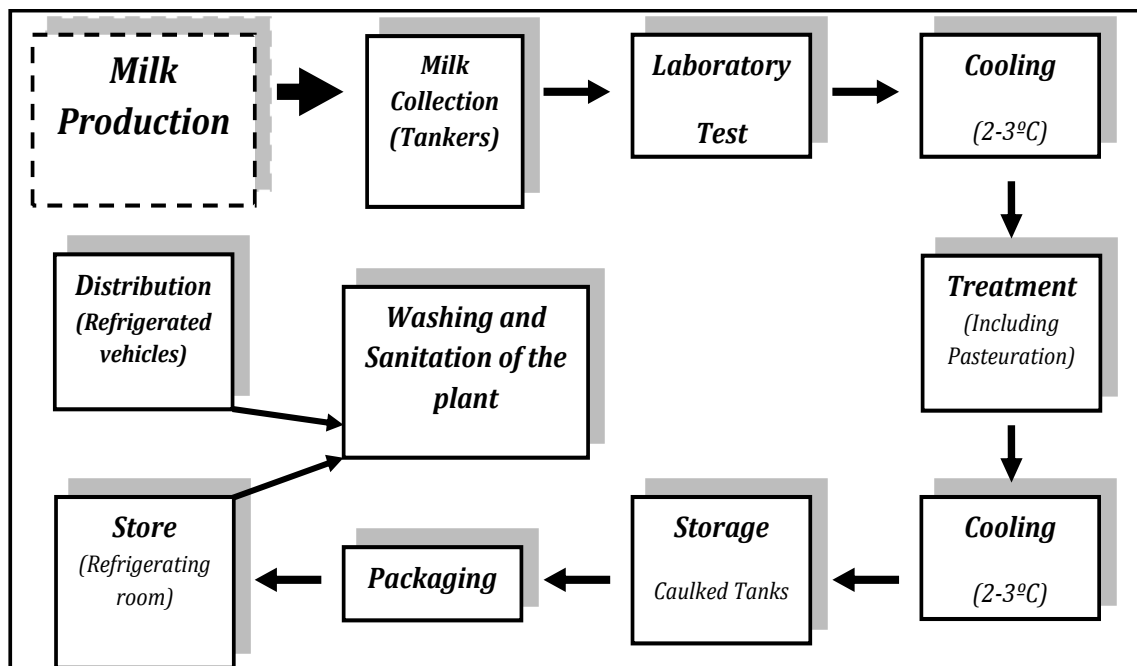
Figure 3 – Milk production process

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[6] We should bear in mind that this damage estimates refer to a very small kiln and are not be extended to average plants operating in the same sector.

The production process of the fresh milk starts with the daily milk collection from the local producers by means of tankers, followed by a preliminary laboratory test of the adequacy of its characteristics.

Then the milk, already cooled in the previous phases, is further cooled down to 4° C. The treatment phases, including pasteurization, follow this preliminary stage. Pasteurization is a very important process aimed at sanitizing the product and increasing its commercial life and requires a warming at a temperature of 76° C.

After the treatments, the milk, cooled again at a temperature of 2-3°, is stored in caulked tanks, and then sent to the packaging process, stored in refrigerating rooms and finally distributed through refrigerated vehicles.

At the end of the process all the plants have to be washed and sanitized.

The fresh cream production follows a similar process, although on a smaller scale and with a slightly different thermal program.

Both production processes are strongly dependent on electricity and continuity of supply plays a crucial role. In fact, it is relevant to remark that, when dealing with fresh milk, the production cannot be shifted from one day to another. Even if the production process starts at 4 AM and stops at about 2 PM, a delay of few hours creates relevant problems in the product distribution for the following day.

In particular, electricity is employed for the following purposes:

- Operation of all machinery in production lines;

- Production of steam for the heat exchangers employed in pasteurization;

- Production of icy water employed in pasteurization and in the cooling processes;

- Cooling of the refrigerating rooms.

In such operational context, an electricity interruption can generate relevant inconvenience, especially if it occurs in the "peak" production hours, namely between 6 AM and 1 PM, when most of the processes are operating. Although some machinery is equipped with accumulators, these are largely not sufficient to

ensure the operation of the whole plant. Moreover, the firm does not possess its own generators. In a specific case of need occurred in 2003 (due to a blown out voltage transformer), the firm could retrieve a back-up facility thanks to the electricity maintenance company. In this case, the power provided was sufficient to face the emergency, letting the core processes restart in about 8 hours, but not to ensure the ordinary management of the production.

Pasteurization is by far the most sensitive process: even a very short power interruption (few minutes) can generate a fall/rise in the operational temperatures (by stopping the pumps circulating hot and icy water), which makes necessary to stop the production. In fact, only very small deviations from the physiological pasteurization temperature (76° C) are possible: Italian regulations do not allow warming the milk below 72.5° C in the process.

Nevertheless, quality rules adopted by the firm set the limit at 74° C. When the temperature of pasteurization is lower than this, the process stops and the milk contained in the pasteurizer is lost (the capacity is 600 litres). In fact, milk cannot undergo more than one thermal treatment. Case-by-case evaluations are necessary to decide whether the material must be disposed of or it can be allocated to an alternative use (e.g. cheese production). If we consider an average price for raw milk of about 45 €/100 lt., we can estimate a direct damage of 270 € (approximately 2% of the daily added value)[7].

This cost can be considered as fixed with respect to the blackout duration, since, as mentioned above, it occurs even in case of very short interruptions. Moreover, production cannot be re-started immediately, since washing and sanitization activities of the machinery are needed.

Another point relates to the potential damages to electronic equipment, which, although protected, are in some cases very sensitive to transient overvoltage. Short interruptions do not generate other relevant problems. Longer blackouts, instead, can have important consequences if they impact on the preservation of the cold chain. Finally, medium length interruptions (i.e. up to 6 hours) are not likely to

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[7] Our estimate.

damage the product stored in tanks or in the refrigerating rooms, since the caulking ensures enough autonomy.

The main problems related to interruptions lasting several hours and occurring in the "peak" production time refer to stops in the production cycle.

Clearly the problem is more relevant if the blackout is unplanned. Since fresh milk is a daily product, lost production cannot be recovered in the following days. Moreover, the inconvenience could also affect the upstream branch of the supply chain, since the storage capacity of the producers is limited, and the milk has to be collected every day.

Finally market issues have to be considered. Fresh milk is a highly competitive sector, and punctuality plays a crucial role in the relationship with customers, generating an organization much similar to a Just-In-Time approach. Not respecting the supply deadline can compromise the contract and potentially lead to a loss of customers. The economic impact for the firm is huge (constituting probably the main source of damage), though difficult to be quantified.

4. Conclusions and learned lessons

This paper is based on three case studies highlighting different types of additional costs that can occur to firms in case of blackouts. They are represented by breakage of machinery and infrastructures, long reactivation procedures after blackout or after more serious damages, or from waste of raw or semi-processed materials due to the stop of production lines. Another item which has to be considered but which is very difficult to quantify is the effect that a delay in supply worsens the firm image. In case of very competitive industries, or of periods of peak productions this can represent the greatest source of damage. Regarding our study this damage is particularly relevant for the case of milk production, which has a very short time-to-market due to the need of daily supply of resellers. The production cycle in this case is in fact very short, and the product is dispatched in hours after it is produced.

Table 2 – Resume of the typologies and magnitudes of costs (T.B.E.: To Be Estimated)

CASE	TYPLOGY OF COST	MIN (€)	MAX (€)
Sandwich insulating panels	Reactivation of production lines	180	540
	Equipment damage	1,704	2,424
	Waste	150	450
	Loss of production	7,200	21,600
Cement*	Equipment damage	T.B.E.	
	Restart of kiln	500	1,000
	Loss of production	1,000	1,500
Milk	Waste	270	-
	Equipment damage	T.B.E.	
	Market loss	T.B.E	

*It must be noted here that the plant studied in this work is relatively small. Bigger plants would incur in (much) higher costs.

Although they are, all of them, very different in terms of source and of economic impact and very difficult to quantify, it emerges that their magnitude can be relevant. Nevertheless, these losses can be relevant, but generally the main source of damage remains lost production. This is in general true for all three cases. Table 2 shows the magnitudes of the different types of losses for the three cases. Some of them have to be evaluated due to the lack of cost data (which have not been released by the studied firms).

It is easily seen in the case studies that, although the different cost sources should not be considered as irrelevant, the costs deriving from loss of production (and possible loss of market in the case of milk) become quickly predominant. On the other hand emerging costs tend to be fix respect the black-out duration. In other scenarios they remain fixed for long black-out time duration, and then increase suddenly after a certain threshold.

This effect is due to two phenomena. Firstly the presence of back-up facilities (in one case these have been purchased also to be prepared to face short interruptions in non peak hours for the production process and so accept an interruptible service contract). Indeed, to well assess emerging costs connected to

different black-out durations, a scenario without back-up facilities should be considered, because these investments represent themselves a type of emerging cost incurred to face black-outs. A second element that can cause sudden increases in the cost caused by a black-out are legal, professional or company quality standards. For example, if temperature is a variable affecting the quality of the output of the process, quality standards may include the obligation to throw away semi-processed materials when the temperature trespasses a certain threshold, and since temperature is generally maintained by using electricity dependent techniques, the blackout duration will affect the waste of raw or semi-processed materials due to the stop of production lines. This is very well assessed in our study by the case of milk production. Nevertheless it can be a relevant issue in most food processing industries, in particular for those firms and plants producing fresh material. It is also the case of many post-production facilities (like cold storage plants set for the conservation of fresh food between production and marketing).

Losses are relevant not only for big firms, but also for small firms. Small firms on their side are well aware of the problem, if it concerns them in one of the ways considered in this paper. In fact, the Italian electricity system is rather reliable. No long black-out has been experienced in Italy so far, with the exception of the one occurred in 28/09/2003. Nevertheless, this event – which has started due to a problem occurred outside national borders, did not prove been so much relevant for firms because it occurred on Sunday. . On the other hand other inconveniences, such as brownouts (non-complete drops in voltage) or transient faults (loss of power lasting few seconds) are rather frequent. These very short inconveniences do not cause relevant losses in production, but may immediately generate the emerging costs described in this paper. This is the case for instance of milk production cycle, where a transient might endanger the pasteurization of milk and cream. This explains why the perception of black-outs is that they are not important for firms incurring only in stops in production, while that they are relevant for firms facing emerging costs. The presence of back-up facilities is of course a symptom of the presence of direct emerging costs of different types.

But small firms may not invest huge sums in back-up facilities, due to their relevant cost. In this way usually they are prepared to face the small inconveniences described above, but not long-lasting black-outs.

Finally, also the organization of production matters, since we find that the largest management complication arise when the firms operate with a "Just-in-time" approach. This is again the case of milk production, where the highest cost (which nevertheless has not been possible to estimate) is with no doubt that related to the loss market due in turn to loss of reputation, particularly relevant in case multiple blackouts (and thus multiple missed deliveries of product to the supply chain) might occur in a short period of time. Moreover in some cases, the loss in reputation can sum to fines due to the impossibility to respect contractual terms. Summing up, this study on emerging cost deriving from blackouts shows that such costs may play a relevant part in the more global economic effect of electric blackouts. The present work should be considered only a preliminary one, aiming at tackling a still underexplored topic, also due to the low number of cases studied. Nevertheless, as the case studies are firms producing goods in very different areas, we believe that they can offer a relevant overview on the topic.

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