CASCADING DISASTERS RESEARCH GROUP
INSTITUTE FOR RISK AND DISASTER REDUCTION

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# HOW WELL IS LONDON PREPARED FOR WIDE AREA POWER FAILURES?

## A GAP ANALYSIS FOR THE LONDON RESILIENCE PARTNERSHIP

Pescaroli, G., Turner, S., Gould, T., and Alexander, D.E.

LONDON RESILIENCE

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*Cover Image: London at night (Source: GE Deutschland, WikiCommons).*

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**Other information on cascading effects:** Pescaroli, G., et al. (2017) "Cascading impacts and escalations in wide area power failures" UCL IRDR and London Resilience Special Report 2017-01, UCL Institute for Risk and Disaster Reduction, London. Open Access.

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# Executive summary

This report presents a confidential GAP analysis of London's capability to respond to, and recover from, the cascading effects of wide area power outages. It develops a basic assessment of the perceptions of senior stakeholders on the current status of planning, response, recovery, and the operational resilience of London Resilience (LR).

The following topics have been developed:

- ✓ An introduction to cascading effects, and their implications for emergency management based on our open- access guidelines *Cascading Effects and Escalation in Wide Area Power Failures*.
- ✓ A short outline of the key documentation on power failures produced by LR.
- ✓ A GAP analysis derived from the *Power Failure Workshop held on the 15th of May 2017.*
- ✓ Key reccomandations for the London Resilience Partnership and for policy makers.

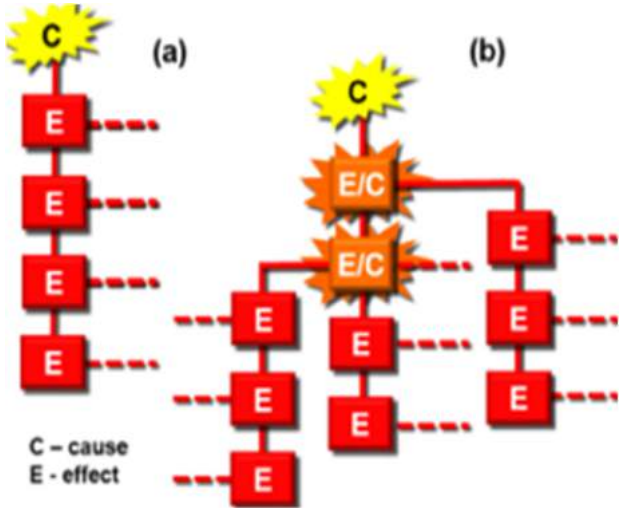
# What are cascading effects?

*Cascading effects* can be defined as:

« The dynamics present in disasters, in which the impact of a physical event or the development of an initial technological or human failure generates a sequence of events in human subsystems that result in physical, social or economic disruption. Thus, an initial impact can trigger other phenomena that lead to consequences with significant magnitudes.

*Cascading effects* are complex and multi-dimensional and evolve constantly over time. They are associated more with the magnitude of vulnerability than with that of hazards. *Low-level hazards can generate broad chain effects if vulnerabilities are widespread in the system or not addressed properly* in sub-systems.

For these reasons, it is possible to isolate the elements of the chain and see them as individual (subsystem) disasters in their own right. In particular, *cascading effects can interact with the secondary or intangible effects of disasters* » (Pescaroli and Alexander 2015). The image below illustrates the differences between: (a) linear paths of chain -effects, and (b) complex paths of cascades. In "cascading disasters", secondary emergencies escalate and become the centre of crisis, challenging the coordination of emergency relief and long -term recovery.



# Implications of wide area power failures

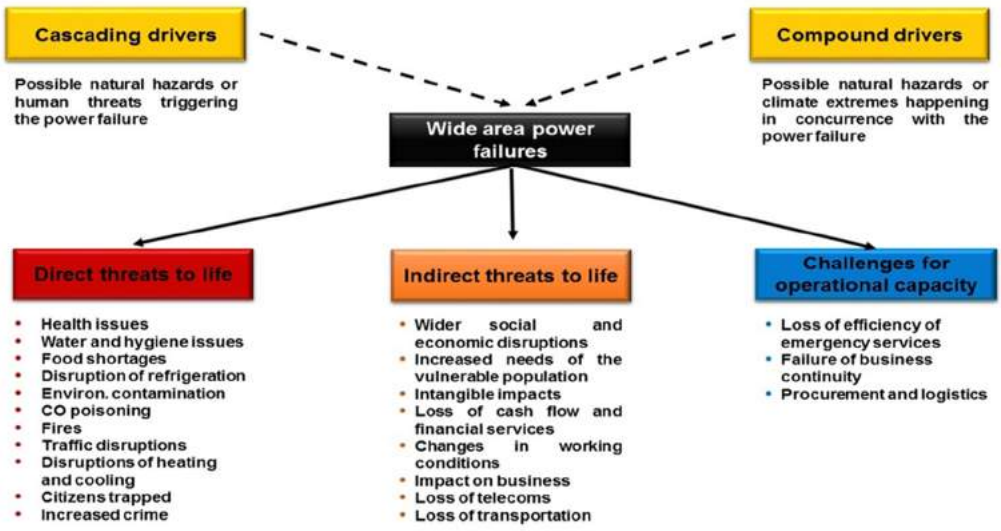
Power failures can be defined as long term or short-term disruptions of electricity, and they are also known as power outages or "blackouts". They can be triggered by both natural and man-made external threat, or caused by internal failures and accidents. Extended power failures can compromise most services and routinely activities, affecting all the aspects of operational management, contingency planning, and business continuity (Petermann 2011, Klinger et al 2014). Thus, it is essential to identify and understand the possible physical, social, and organizational vulberabilities that could escalate the emergency (Pescaroli and Alexander 2016). The sectors impacted by wide area power failures and their cascading effects have been summarized in in the following figure, and are explained in detail in our guidelines *Cascading Effects and Escalation in Wide Area Power Failures* (Pescaroli et al.2017).

# Status of London's protocols

London is one of the most interconnected cities in the world, with a concentration of businesses that are highly dependent on stable electricity supply. A limited power failure of 40 minutes in 2003 affected more than one million people. Small events are relatively frequent, as happened in 2016 in the West End and Soho, but larger disruptions should be considered in planning. The London Risk Register includes two scenarios based on the UK National Risk Assessment (LR 2017):-

1) "Total blackout for up to 5 days with prolonged disruption for up to 14 days due to loss of the National Grid". Its likelihood is "moderate", but its possible impact "catastrophic".

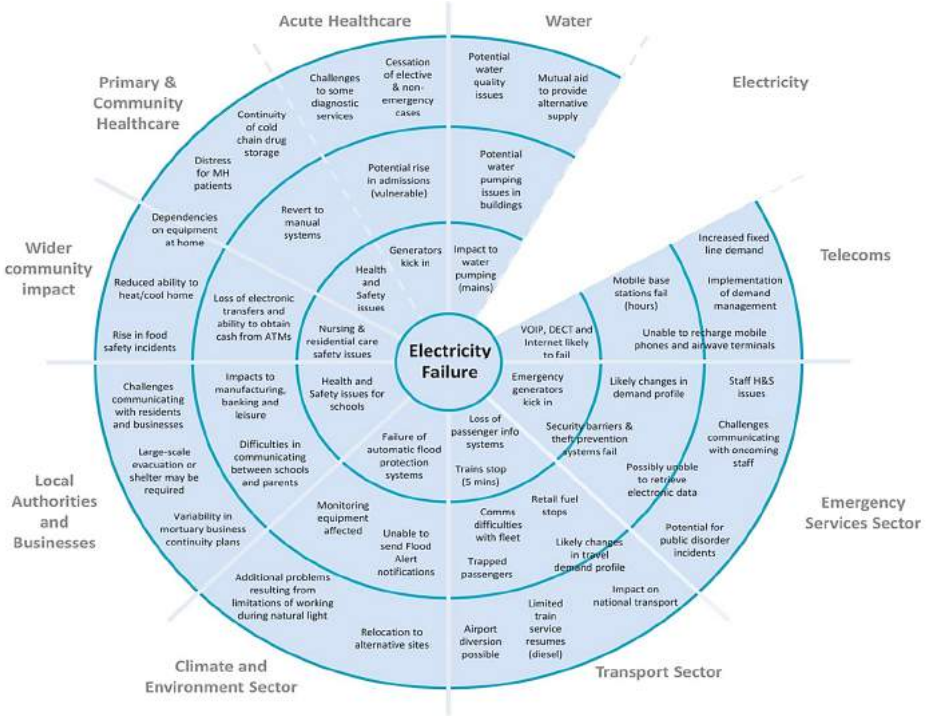
2) Moderate likelihood and major impact "Total shutdown of the electricity supply in Greater London occurring during working week and lasting for 24hours". This actually took place in October 1987.



LR developed in 2014 a plan to activate in case of disruptions of power supply. The document is official, but restricted to the LR partnership. It can be triggered according to the directives of the London Resilience Partnership Strategic Protocol, and it includes a list of responsibilities for the key issues that could emerge (see https://goo.gl/D7JmTt). Our guidelines on Cascading Effects and Escalation in Wide Area Power Failures must be considered as a support tool for its training section.

Moreover, LR created in 2013 a generic model called ANYTOWN to increase the information sharing. A first workshop was held on power failures, which visual output is shown in the figure below. The possible effects and sectors involved are reported in an onion-skin diagram, that expand from its centre to the periphery, including both short- and longer-term effects (Hogan 2013).

Recently, increased concerns have grown over widespread infrastructure failures, associated both with natural hazards, such as geomagnetic storms, and with man made threats, such as cyber attacks. In 2016, the LRF undertook a review of the capacity to respond to wide area power failures, that was complementary to an ongoing work on cascading risk in progress in the Research Group on Cascading Disasters at the UCL Institute for Risk and Disaster Reduction. It was decided to develop together in the project ''Integrating Cascading Disasters in London's Response and Preparedness Strategies''. First, the perceptions of cascading risk, mitigation measures, and training were assessed. Secondly, some open access guidelines were created as suggested in the results to support scenario building and contingency planning (see Pescaroli et al. 2017). Finally, in May 2017, LR promoted a better understanding of how the impacts of wide area power failures could affect London.



# GAP Analysis

We chose to develop a preliminary gap analysis that could incorporate different aspects of emergency planning, training, and organizational and operational resilience (Alexander 2016, Barr et al. 2010, MacFarlane 2015, Florin & Linkov 2016 ). The goal was to provide a basic assessment of perceived levels of preparedness and response and highlight possible areas for improvement. For feasibility reasons, we chose to use questionnaires that could produce some complementary evidence which was provided by the discussion groups.

The questionnaires were self -administered, and anonymous. They required 5-10 minutes to be completed. In order to assure the use of a common terminology, the definition of cascading effects was reported in the first page. It was divided into four sections:

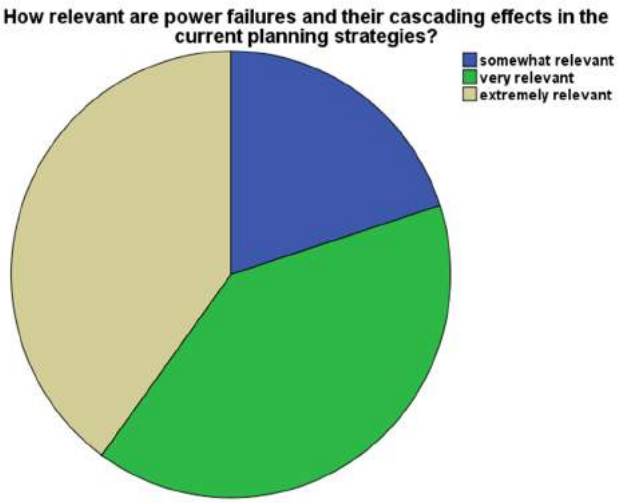
1. General perceptions of power failures and cascading effects in planning;
2. Response and recovery;
3. How to improve the operational resilience;
4. Affiliation of the respondents and feedbacks on the workshop.

The questionnaires were composed of 36 questions, and for most of them a standard scale from 1 (not at all) to 5 (extremely). They were considered valid if a minimum of 70% of the answers were provided.

In conclusion, a total of 26 asssessments were included. It was assumed that the participants were senior level, given the nature of the workshop. The majority of them were category 1 responders (60.9%), with smaller representation of businesses (13%), category 2 responders and academia (8.7% each), NGOs and other (4.3% each). Among them there was a reasonable understanding of London's strategic coordination protocol (M=3.75, SD=0.84), and the broader strategic priorites on power failures (M=3.79, SD=0.58). There was a clear gender imbalance among the reponders, as 80% were males.

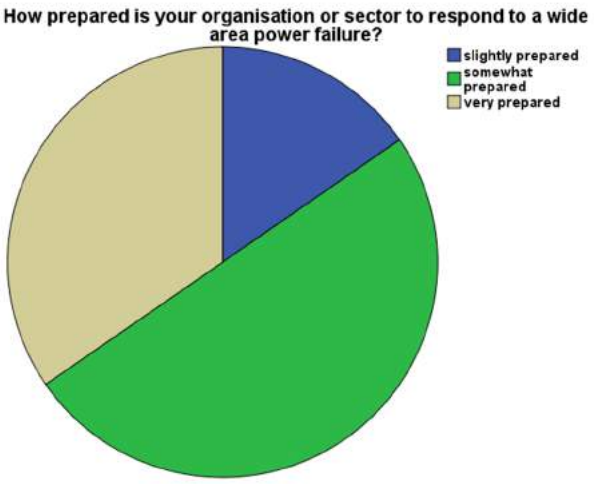
# Results-Section 1

Most of the answers (80% equally distributed) defined power failures as "very" or "extremely" relevant to the current planning strategies (M=4.2, SD=0.76), and highlighted that the respondents believed that power failures can extremely affect society (M=4.69, SD=0.47).

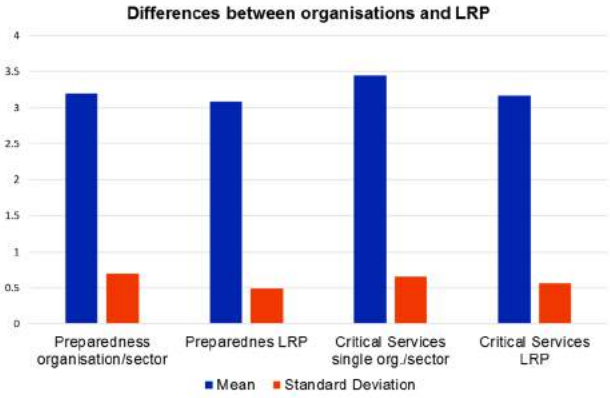


The paticipants perceived that their organisations or sectors were somewhat prepared to respond to a wide- area power failure (M= 3.19, SD=0.69). None of them suggested the lowest or the highest value, which suggests that some work has been done but not fully implemented.

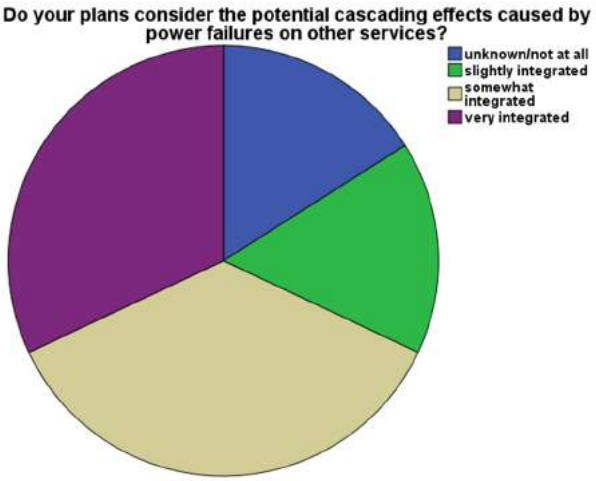
The preparedness levels increased slightly considering the capacity of the respondents' own organisations to assure the delivery of critical services (M=3.45, SD=0.65). In this case, some of them highlighted levels of preparedness as described in the figure below.



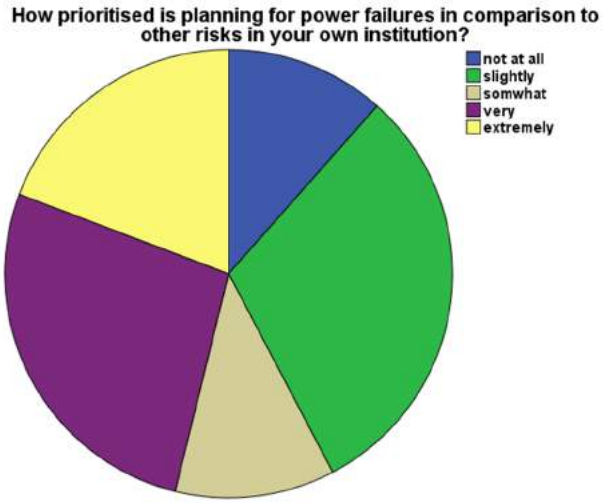

When the Preparendess of the LRP as a whole is considered, it is clearthe LR partnership is only moderately prepared (M=3.08, SD=0.50). Again, as a whole, the LRP shows a perceived capacity to deliver critical services lower than the values attributed previously (M=3.16, SD=0.56). Although the difference between the perception of the orgnisations and the LRP is quite small, it is reflected in all the questions and standard deviations (see figure below). It may be argued that this could be associated with a lack of information sharing among the agencies, but in any case this should be investigated further in order to identify which may be the perceived vulnerabilities in the partnership.




It is wildely agreed that the loss of essential services can pose a great risk to life and personal security in the nearly totality of cases (M= 4.30, SD= 0.61). The vast majority of the participants have specific plans to respond to wide are power failures (64%), most of which have been updated in the last two years (72.7%). The plans tend much less to consider the potential cascading effects caused by power failures on other services (M=2.8, SD =1.06). Although no insititution is very highly integrated at that point, the values are fragmented ( see figure below) and suggest the need for better standards and policies.



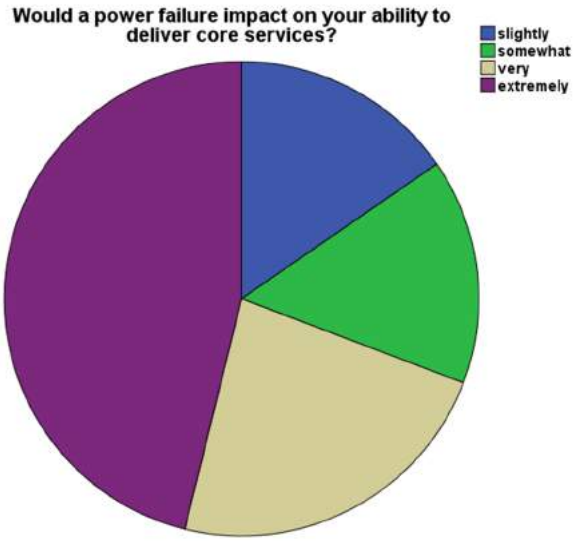
Some similar fragmentation is visible in the values attributed to the inclusion of cascading effects of power failures during concurrent events such as floods (M=3.0, SD= 0.81). In conclusion, the results point out that the priority attributed to planning for power failures in comparison to other risk varies substantially across the organisations (M=3.11, SD=1.36). Again, this should become a subject matter for policy makers.



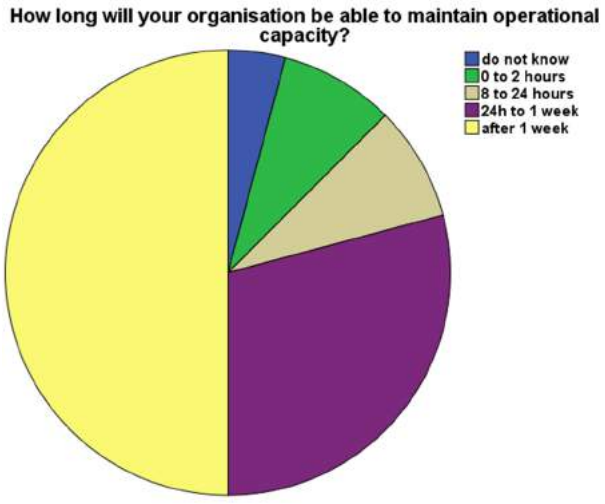

# Results-Section 2

In the second part of the questionnaires, a strong variability emerges, and that may point to significant differences in the response capacity of organisations.

It is agreed that power failures can strongly impact each organisation's ability to deliver core services, although there are differences between the answers =(M=4.0, SD=1.13). In this case, 46% of the answers suggest that power failures will definitively impact the capacity to deliver core services, while none of the respondents suggested the possibility of having no impact at all.

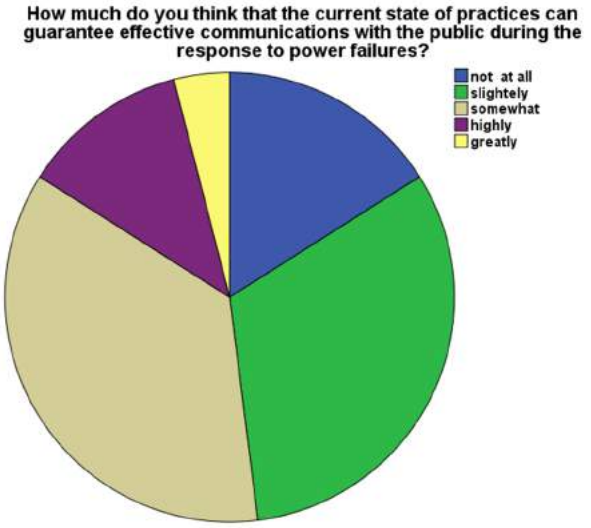



Differences have been pointed out how long each organisation is estimated to be able to maintain operational capacity. Half of the participants suggested the period between the early impact and one week, while 50% of them highlighted the possibility to maintain operational capacity for more than one week (figure below). This could be determined by internal thresholds and definitions of "operational capacity", and further analysis should understand such differences for improving strategic approaches.

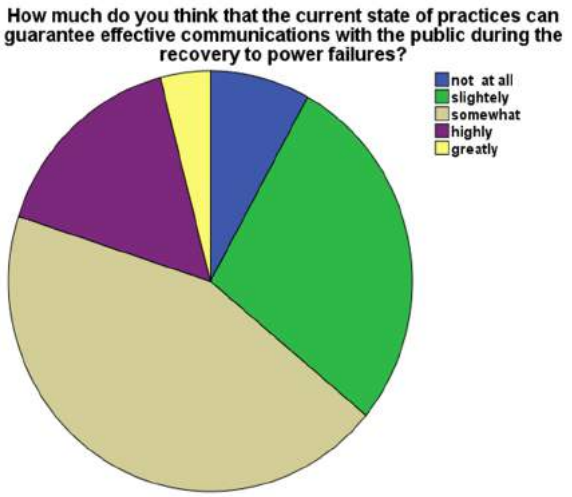


The respondents gave moderate weight to information sharing within their organisation (M=3.33, SD=0.70). They gave slightly less weight to information sharing with with other organisations (M=3.16, SD=0.89). They were more confident of the capacity of personnel to maintain the operational capacity (M= 3.60, SD=0.70), and they were yet more confident in the ability to manage the recovery after a power failure (M=3.68, SD=1.06).

A much less optimistic view appears from the perception of how much the current state of practice can guarantee communication with the public during the response and recovery phases. These two elements seem to be some of the most evident gaps showed by the analysis. First, the respondents think that the current state of practice can partially guarantee an effective communication during the response (M=2.56, SD=1.04).



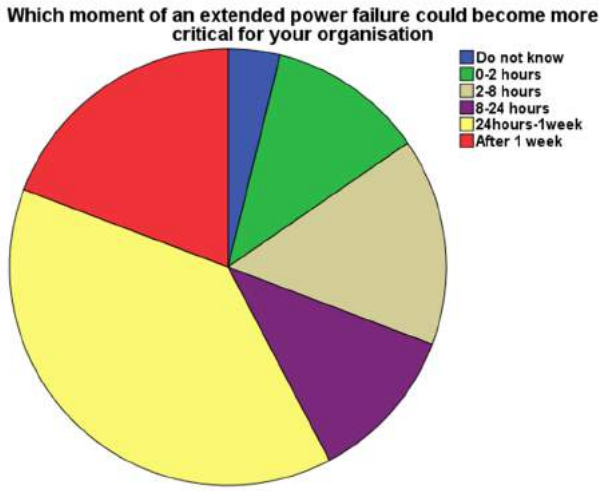

The figure above shows that approximately 36% of the responses were concentrated between “not at all” and “slightly”, reaching 80% when an average level is included. It is possible that some organisations may have more consolidated practices, but they are a small minority. This is one of the lowest results in the questionnaire, and it suggests the need for strong action. Morevoer, the practices of communication are perceived slightly more effective in the recovery phase (M=2.80, SD=0.95), but the gap remains evident, as shown in the figure below.



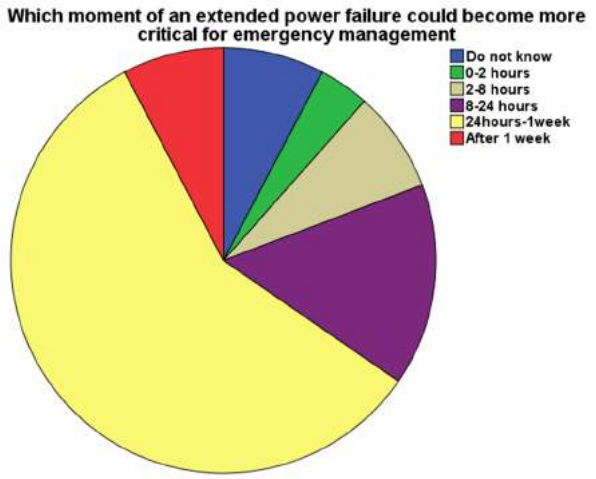

In concluding Section 2, the participants were asked to assess which moment of an extended power failure could become the most critical for their organization and for emergency management at large.

The most critical period for an organisation is very clearly the one between 24h and 1 week (43% answers),

more than 1 week (20%). There are nearly equivalent values of approx. 10% for the ranges less than 24h, and they highlight differences between organisations. Two respondents chose multiple options (not included in the figure below): In one case, the period beween 24 hours and one week, was chosen together with after one week; In a second case, the period between 0 an 2 hours and the one between 24 hours and 1 week was chosen. This probably highlighted the peak in the initial demand and the exhaustion of resources.




The same time frame between 24h and 1 week is highlighted even more for emergency management (nearly 56%), that is in line what what could be expected with the loss of efficiency due to pressure on personnel. In this case, the second option that emerges is 8-24 hours (approximately 15%), followed by one week (11%). All the other answers are much less relevant. Even in this case, there was a double answer that highlighted both 24hours and 1 week, and more than one week (not reported in the table below). Comparing the two tables, it could be argued that some of the respondents consider their own organisation to be more reliable than general emergency management until it reachs a breaking point, which would occur after one week.



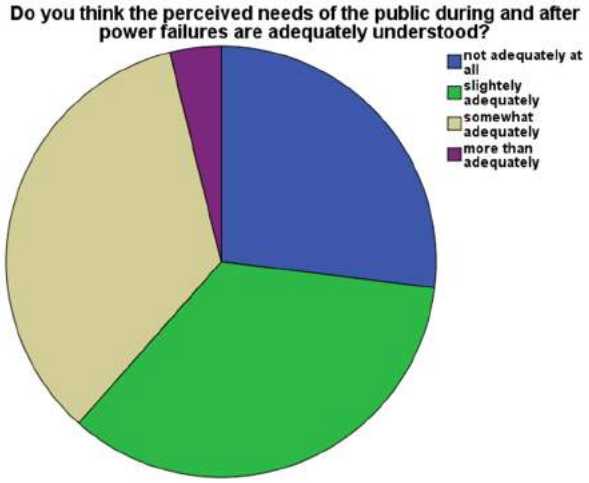

# Results -Section 3

Training levels were adeguate, as the majority of respondents had altrady exercised on their response to power failures (66.7%). They were awareof wider impact analysis and impact trees (70.8%), as well as other forward looking tools (70.8%). However, despite the good result, it may be argued that the 30% level could be concerning anyway for the seniority level of the participants.

Finally, there is agreement that the current response could be improved significatively (M =3.64, SD=0.70), and the majority of the participants suggested there is potential for improving substantially the response (64%).

In order to improve coordination of emergency response, it was considered necessary to promote better definition of tipping points of acceptable risk and uncertainty (M=3.61, SD=0.84). This was considered very helpful in the majority of cases (61.5%). The perceived utility of localised energy sources for improving resilience was much more fragmented (M=3.32, SD=1.14). Those two items were already integrated in the questionnaires for the ANYTOWN Workshop (N=54). It was suggested that a common definition of 'tipping points' may be needed (M=3.76, SD=±0.77), in line with the findings of this report. Instead, higher values were attributed with the potential of localised energy sources with lower fragmentation of answers (M=3.75, SD=±0.95). This could reflect scepticism on their capacity to increase the resilience to blackouts.

Finally, the results show what is likely be the biggest gap in the current situation. Most of the respondents believed that the perceived needs of the public during and after power failures are only slightly understood (M=2.15, SD=0.88). The figure below shows the concentration of answers.




# Correlations between answers

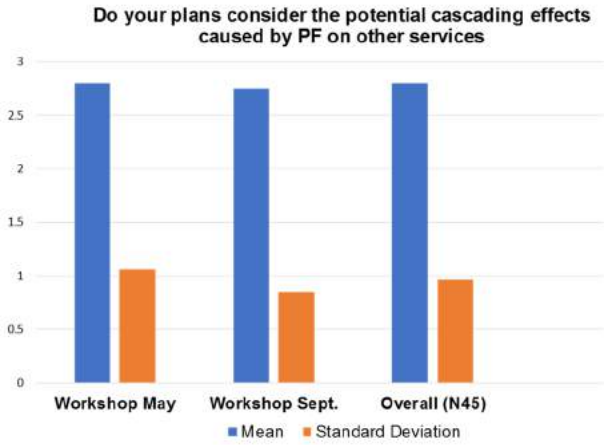
The analysis revealed many correlations between the answers, but it must be noted that they may have been influenced by the limitations of the dataset. We suggest extending the questionnaire in the future to help identify possible patterns. In the following paragraphs we report the most significant evidence found: -

- The preparedness of each organisation to respond to wide-area power failures was very substantial and it correlated with the prioritisation of planning for power failures over other risks (r=.777, n=26, p=0.000). This may highlight the importance of using the risk registers properly.
- The respondent who perceived the LRP to be more prepared to respond to wide-area power failures strongly believed that the LRP was also more prepared to deliver critical services during similar events (r=0.714, n=24, p=0.000).
- Adequate practices of communication with the public during the response to power failures were strongly correlated with adequate practices of communication with the public during the recovery to power failures (r=0.700, n=25, p=0.000).
- The values attributed to the extent to which staff would be able to maintain operational capacity were associated with the preparedness of the organisation to deliver critical services (r=0.699, n=24, p=0.000).

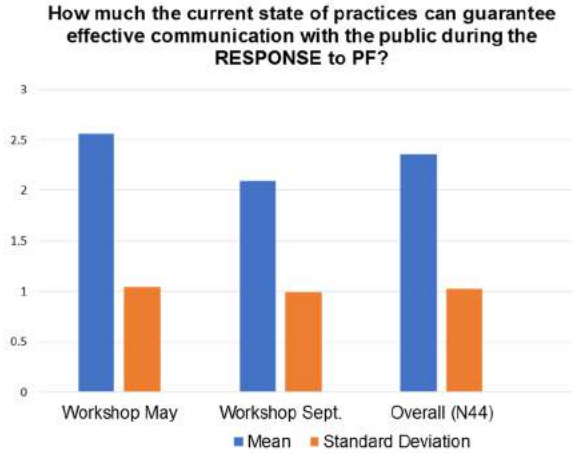
# Follow - up

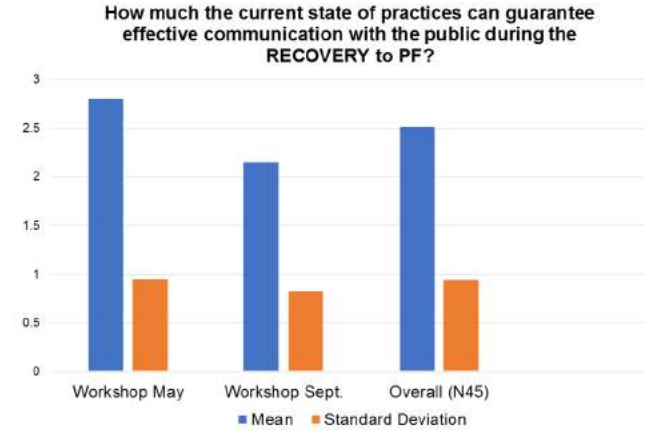
In order to extend the data base, the four questions with lower results were asked for a second time in September 2017. Twenty valid forms were received and the following results were obtained:-

- The actual plans tend to not consider adequately the potential for cascading effects caused by power failures on other services (M=2.75, SD =0.85). This result is, basically, the same as that obtained with the first questionnaires (figure below).

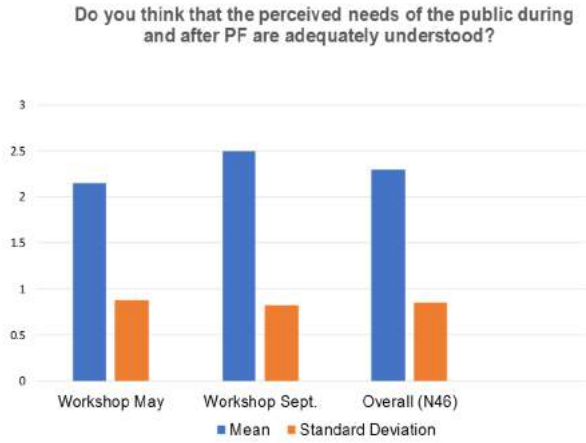



- The respondents believe that the current state of practice cannot guarantee effective communication with the public during the response to power failures (M=2.1, SD=0.99), or during the recovery from it (M=2.15, SD=0.82). These results are worse than those obtained in the previous data collection and they point out the need for action as highlighted in the following figures.




- Finally, most of the respondents believed that the perceived needs of the public during and after power failures are poorly understood (M=2.5, SD=0.82). In this case, the overall perception improved, but it remains at an inadequate level with similar fragmentation of answers (see figure, below).



To sum up, the questionnaires collected in September 2017 confirmed the results. The variations in the answers are relatively small and does not contradict the evidence we had already, while it could be considered that the differences in the focus of the workshop could be influencing the answers.

# Conclusions and Recommendations

This short assessment does not pretend to be exhaustive and has limitations, but must be intended as a first step for a better assessment of the capacity to respond to wider area power failures. The following points should be considered in the near future:

- **The participants pointed out an unequivocal problem in the lack of understanding of what the public may need during and after power failures**. This is the most critical finding, as it should orient the practices of communication and the overall effectiveness of emergency coordination. This finding is in line with the theoretical approach to cascading disasters. In the recent years, behaviour associated with the search and use of informations has evolved, becoming more dependent on electricity (e.g. Internet and smartphones). This is particularly relevant in London, where the interconnections and the role of new technologies are very broad. **We may reccomend a questionnaire and focus group to be developed to understand better how and what to say in case of blackouts**. Due to the highly interconnected nature of London, it could be useful to extend the information gathering to other urban and rural areas.
- **A clear gap highlighted by the responders is associated with the practices for communicating with the public during the response and the recovery phases.** This is in line with some of the points that emerged from the workshop, and requires strong action. There is the strong tendency to see together the communication in the response and in the recovery phase, highlighting the need for better planning.

- Power failures can affect the capacity of the LRP to deliver core services, though differences between organisations exist. **We reccomand to explore better the common vulnerabilities and potential synergies for increasing operational resilience.** Indeed, a general fragmentation in the answers was observed. First,it could be desirable to extend the dataset in order to consolidate the evidence and identify possible trends. Secondly, it could be beneficial to produce a focused analysis to understand better the differences among the organisations, including both Cat.1 and 2 Cat. 2 responders, but also in a more systematic way businesses, enterpriseses and civil society.
- **The most challenging period** perceived by the organisations and emergency management is perceived to be the one **between 24 hours and 1 week** after the impact. Similar evidence can be found in a report for the German Bundestag (Petermann et al. 2011). **Further analysis should try to explore which could be the operational thresholds, and the lifelines that should be prioritised** for maintaining operational resilience.
- **It is needed to integrate better in planning the cascading effects caused by power failures on other sectors.** In particular, this can be correlated with other elments such as the consideration of what extent personnel will keep operational capacity. This point is complementary to the suggestion above, and more in general with the need of improving the assessement of common vulnerabilities and synergies in the LRP.
- **Training levels should be improved and should become more uniform** in particular for senior- level and gold level management. This element may also be associated with the need to improve trust and information sharing withing the LRP.
- **Power failures should be more prioritised in planning**, in line with the assessement made in the London Risk Register.

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# UCL-IRDR & London Resilience Special Report 2017-02

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CASCADING DISASTERS RESEARCH GROUP. Our mission is to promote a cross-disciplinary approach to the emerging topic of cascading risk, involving the public sector, private enterprises and communities in impact-oriented collaborations.

LONDON RESILIENCE (LR) coordinates institutions and communities to prevent, handle, recover and learn from disruption, and adapt to change.

BECOME A MEMBER OF THE IRDR. The IRDR aims to bring together the expertise available at University College London in terms of research, teaching and knowledge exchange to overcome the barriers to understanding risk and reducing the impact of disasters.