Improving the robustness of urban electricity networks IRENE

D3.2 – Policy definition and methodologies for decision support

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1 INTRODUCTION

This deliverable extends the results obtained in Task 1.2 by describing how the tools developed by the IRENE project could be applied when planning for a city's energy resilience. As such it does not present a definitive answer but rather provides some insights as to how, with appropriate policies and methodologies, various city stakeholders could collaborate to help plan for a city grid configuration that promotes resilience; collectively this begins to establish a 'collaborative framework' through which city stakeholders can engage in energy resilience planning.

The deliverable presents two key elements that could assist a city planner when evaluating their energy resilience. These are a:

- Grid assessment policy (Section 2) - describing a policy[1] focused on assessing the resilience of a particular smart grid configuration; and
- Criticality assessment methodology (Section 3) - a methodology[2] for assigning criticality to grid components as one input to the evaluation of specific smart grid configurations.

Section 4 (Application) considers how this policy and methodology could be applied in practice. We use the UK Spatial Planning System and the Dutch resilience to illustrate how these ideas might be applied (while acknowledging that different EU states have different planning systems). This section also explores the idea of a 'collaborative framework' as a basis for assembling key stakeholders and providing them with the resources (software tools, policies, role descriptions, methodology) and overall process that will help them assess the resilience of their city grids. We also discuss how these ideas are being evaluated through a series of stakeholder workshops.

Section 5 (Conclusions) draws out some insights as to the realities of applying these ideas in practice and considers what further research could be undertaken.

[1] A set of principles and/or constraints that will guide decision making

[2] A body of practices, rules and procedures

2 GRID ASSESSMENT POLICY

The term ‘policy’ is used here to describe a set of principles and/or constraints that will guide decision making. Specifically this decision making has a well-defined scope and is limited to those decisions that a city planner can make (at least in principle) when evaluating a particular grid configuration in terms of its resilience to threats that could lead to serious and prolonged power outages. In some case the city planner’s decisions will be based on recommendation from other stakeholders or domain experts or such as DNOs or security experts that need to get involved in the planning process. The aim of IRENE is to provide means to evaluate a given solution for changes in resilience. It is not the aim to provide a solution for how to upgrade the grid in order to improve its resilience.

Adopting the Grid Assessment Policy implies that the city planner (role) is going to apply (to some degree) the approach to assessing the resilience of any particular grid configuration as made explicit by the IRENE project’s Open Modelling Framework [1]. This framework established a workflow through which a city planner, engaging key expertise as necessary, can systematically evaluate a grid configuration assessing threats, exploring local and grid wide mitigation options, proposing possible grid changes, in turn which may be subject to new threats. This cycle of activities can be repeated as necessary. The Open Modelling Framework is presented in Figure 1.

The application of the Grid Assessment Policy can help a city planner to understand the resilience of their current grid and explore possible changes to make improvements. The application of the policy implies that the City Planner will almost certainly need to engage various experts, for example when exploring mitigation strategies that might require security expertise or when exploring new topologies that need energy flow modelling expertise.

2.1 GRID ASSESSMENT AND PLANNING WORKFLOW

The aim of the planning process developed by IRENE is to help city planners to assess the impact of grid changes on its resilience. The process is supported by a number of easy to use tools that can help skilled city planners that have support from experts with the appropriate domain knowledge to do this assessment. The process consist of five steps that need to be performed iteratively until the required resilience targets are met by the updated grid infrastructure as shown in Figure 1. The complete workflow is instead in Figure 2, also described in D4.2 [1].

2.1.1 Initialisation

In a first step of the planning process the city planner defines in collaboration with other city stakeholders the planned grid changes and the resilience targets to be met by the updated grid. The reason for grid updates are manifold but changes fall in one of the categories a) planned evolutions, b) implementation of mitigation strategies or specific topology updates [1]. While grid infrastructure updates need to be agreed upon mainly with the responsible DSO several stakeholders need to get involved when defining resilience targets that should be met by the updated grid. Stakeholders relevant for defining these targets include citizens, business representatives and operators of critical infrastructures such as health care, food supply, or public safety and security organizations. They all need to get involved they might get affected by planned changes or updates to the power grid.

The initialization of the workflow includes the definition of the planned grid changes and the current grid topology. Changes that need be considered are topology updates including the addition of generators or communication infrastructure and addition of new loads such as supermarkets, outpatient clinics or residential buildings. Once the grid changes have been defined the threat analysis can be conducted on the updated grid infrastructure. In order to perform the threat analysis an incremental approach for threat analysis should be followed such that the result of the threat analysis will provide the list of emerging threats assuming associated with the introduced grid changes.

To be compliant with this methodology, the investigated scenario must be composed of the different descriptions created in this phase that include:

- a baseline scenario, that summarize the starting point of the city scenario we want to analyse;
- the update actions initiated by the city's administration in order to improve the smartness of the grid or simply to adapt the scenario to newer requirements;
- a target context, that is obtained from the composition of different evolution steps and that represents a sort of expected status of the city in some years from present time.

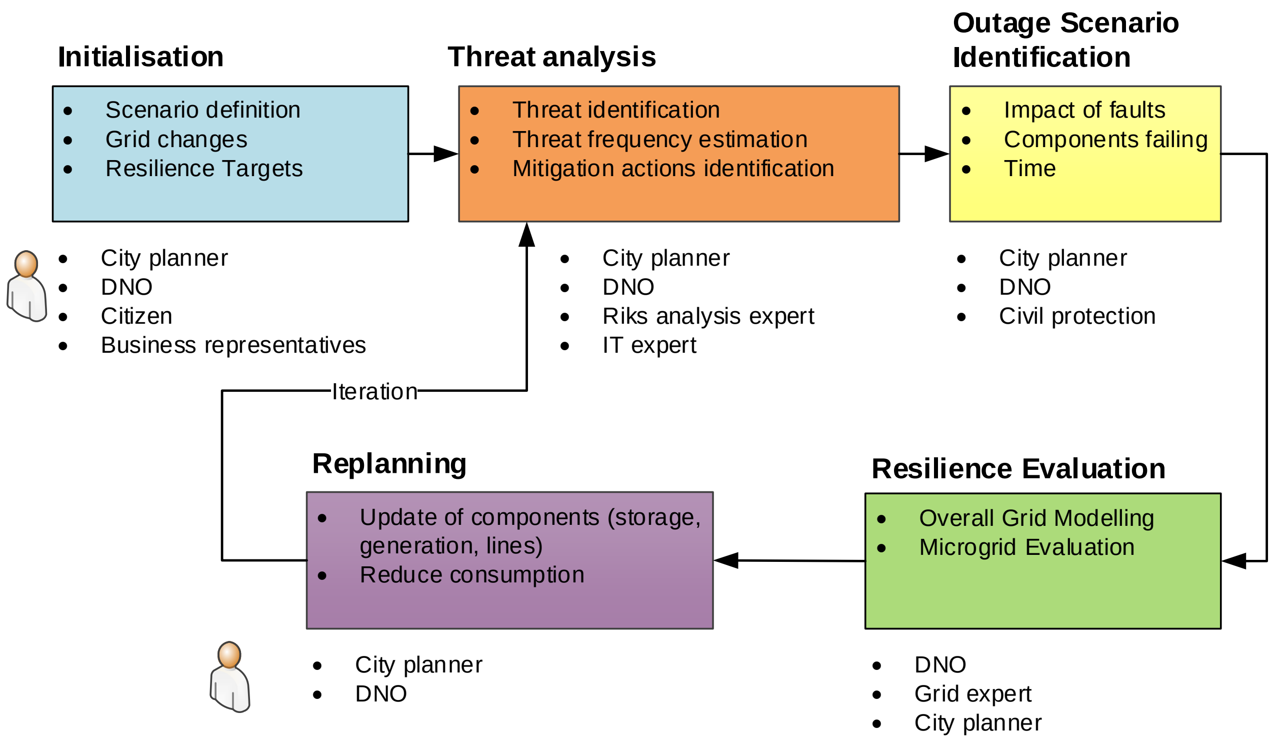

Figure 1: IRENE workflow

2.1.2 Threat analysis

The aim of the threat analysis is to identify threats that are related to the grid updates and constitute a potential source of emergent threats. Threats identified in this step need to be addressed by the actors involved in grid planning and operation (stakeholders, DNOs, city planners, regulators) by using the collaboration framework. In particular, emerging threats will most likely require a deeper collaboration of the different actors in order to be predicted and/or mitigated efficiently.

The proposed methodology is intended to operate according to changes in the scenario, focusing on threats emerging through the abovementioned changes (here an asset oriented approach as proposed by NIST [2] is followed). Out of 102 threats the IRENE project identified a set of 38 relevant for smart grids.

Based on the identified emerging threats, a mitigation strategy needs to be chosen for different types of threats. For most threats it will be feasible to find and implement appropriate controls that address these threats. However, there will also be a number of residual threats where mitigation is technically or economically not viable. These residual threats can still lead to outages. This step requires the involvement of risk analyst, power grid, and IT experts.

2.1.3 Outage scenario identification

Once the list of residual threats has been identified, the impact of these threats needs to be analysed. If one or several of these threats are not mitigated by suitable controls they potentially can cause a threat event that leads to an outage. In this step electricity grid and IT experts have to define the outage scenarios based on the threats that have not been covered by controls. Outage scenarios consider the parts of the grid that are affected by the outage and the expected duration of the outage.

2.1.4 Resilience evaluation

In ths resilience evaluation step the resilience of the grid towards different kinds of outage scenarios is evaluated. Evaluation is done by using the tools developed within the project. The response mechanism to outage scenarios considered by IRENE are microgrids. The tools help to evaluate the chosen grid layout and setting of the microgrid. We distinguish two different cases: a) a complete outage where no supply is provided by the upstream grid and b) a partial outage where limited supply is available due to e.g. single line failures and available power is not sufficient to supply all loads. The result of this step is the assessment if the chosen configuration can withstand the outage scenario or if further grid changes are required to meet the resilience requirements. If the grid assessment was sucessful ther workflow stops here. Otherwise new grid changes need to be reconsidered.

2.1.5 Re-planning

New grid changes are required to meet the requirements could be the either the introduction of additional generation or new lines as well as the reduction of loads. In case it is figured out that the grid is not able to survive the outage scenario and hence forth new grid changes are needed to be considered. These grid changes have to be developed by the DNO with the support of the city planner. After suitable grid changes have been defined the process will be re-evaluated. In this new process the indentified grid changes and their impact on grid resilience will be evaluated.

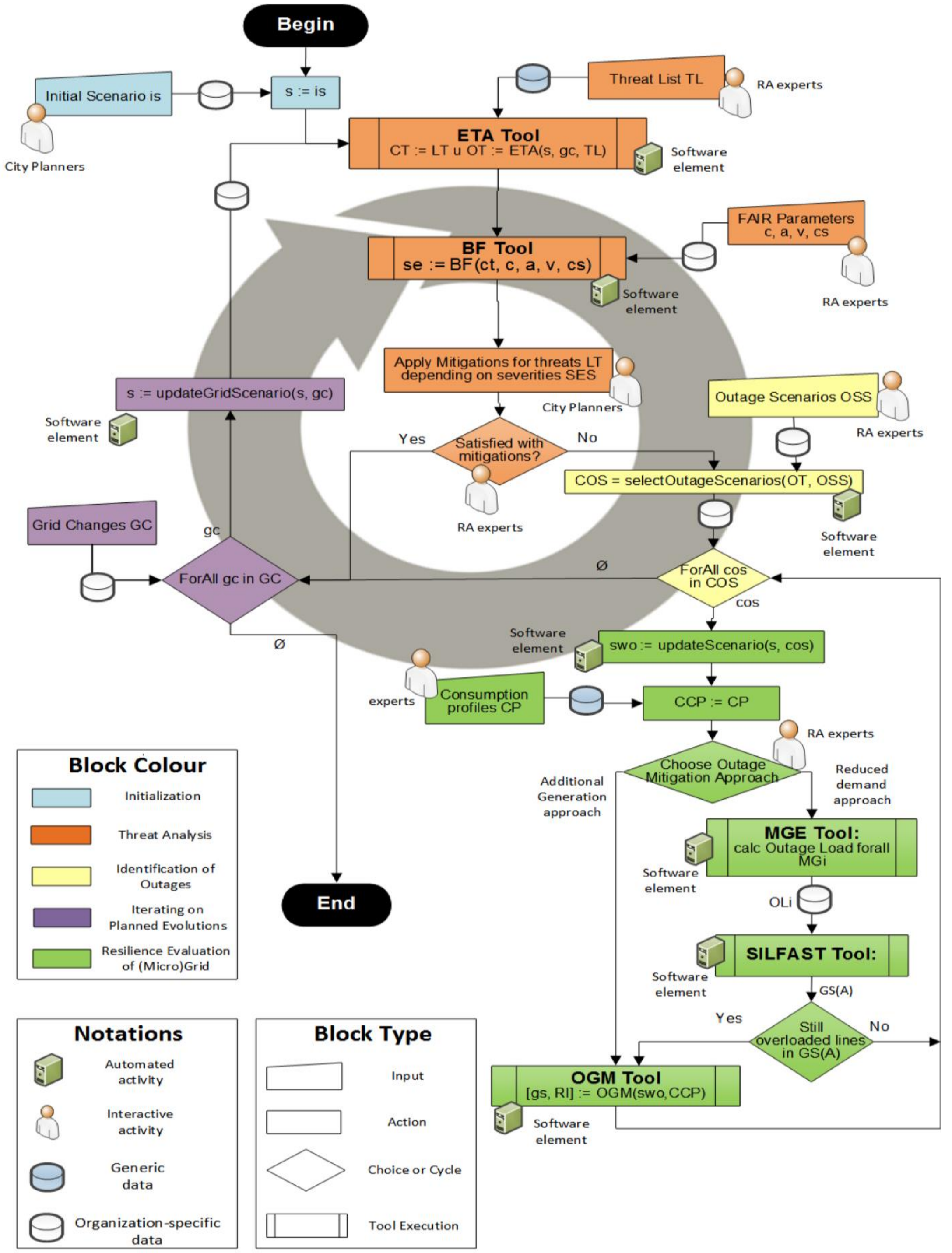

Figure 2: Detailed IRENE Workflow

2.2 CRITICALITY ASSESSMENT METHODOLOGY

The term 'methodology' is used here to describe a body of practices, rules and procedures that together help an actor(s) deliver on a particular objective. The objective here being to assess the criticality of grid loads as an input to the Open Modelling Framework described in Section 2 above (Grid Assessment Policy).

The term 'criticality' can be defined as 'the quality, state, or degree of being of the highest importance' and here we are explicitly referring to grid components.

An assessment of criticality rating as an input to our methodology is required to provide a level of confidence to the city planner in managing a particular grid configuration. This assessment should be applied quantitatively although it is understood that a precise measurement will not always be practical - more often than not, it will be down to the experience of the planner or industry professional to provide this rating.

This section starts by considering how 'criticality' can be quantified. It then goes on to consider various 'dimensions' of criticality in terms of the consequences from a human, environmental and economic perspective. Moreover, it addresses the issue of infrastructure interdependencies by taking into account the significance of one infrastructure on the proper functioning of another infrastructure. It finishes by considering how these insights can be used when assessing the critically of the components within any particular grid configuration.

With regard to the consequences of any failure, a qualitative rather than quantitative approach to the rating of criticality is required. We start by reviewing examples from wider industry. A standard event would be defined by its consequences along three distinct axes; human, environmental, and infrastructure.

2.3 Human consequences

Within the United Kingdom, the Health and Safety Executive (HSE) amongst others, provide monetary equivalents for this (a life is worth *x* if staff, *y* if public etc.) (see Table 1). Such monetization figures vary widely with international geography.

1.0	Loss of multiple lives
0.8	Loss of single life
0.7	Multiple disablements
0.6	Single disablement
0.3	Expectation of non-permanent harm
0.0	No significant human impact

Table 1: Risk to life / quality of life

2.4 Environmental consequences

The monetization of environmental consequences will typically be related to fines, costs of clean-up or an assessment of secondary effects upon the health and wellbeing of local populations. There is monetisation data published by Dept. Homeland Security (USA) in cyber incident papers see Table 2.

1.0	Release / contamination resulting in permanent damage, denial of access or utility
0.8	Widespread negative effect, with significant costs or impractical clean-up. No permanent effect.
0.5	Multiple releases / contamination. Reversible at reasonable cost.
0.3	Single release / contamination. Reversible at reasonable cost.
0.2	Non reportable event

Table 2: Risk to environment

2.5 Economic Consequences

As outlined in D2.2 [3] there are different approaches for estimating the socio-economic impact of outages exists. We follow an approach where outage costs are estimated based on goods and services produced in an affected area. A measure for this is the gross value added (GVA) what can be derived from statistical data (Table 4). The estimation of outage costs based on GVA can be done by e.g. using the blackout simulator [4] that includes data from 266 European cities and regions.

1	Above 50% of GVA
0,8	From 33% to 50% of GVA
0,6	From 10% to 33% of GVA
0,4	From 1% to 10% of GVA
0,2	Below 1% of GVA

Table 3: Economic consequences

2.6 Infrastructure interdependencies

IRENE deliverable D2.2 highlights the impact of electricity supply interruptions on different infrastructures. Thus, in order to evaluate the criticality of loads, the impact of the lack of electricity can directly lead to the unavailability of other infrastructures. If there is no immediate impact there might be an impact after e.g. 24 hours when no backup power is available anymore. Moreover, it needs to be emphasized that also the proper functioning of the electricity grid depends in particular in the smart grid on e.g. the availability of the ICT infrastructure.

Laugé et al. [5] did a survey of infrastructure interdependencies that is shown in **Fehler! Verweisquelle konnte nicht gefunden werden.** and **Fehler! Verweisquelle konnte nicht gefunden werden.** below. The tables show the results of a survey done with critical infrastructure experts. In order to identify the most critical infrastructures the significance of a potential interruption needs to be considered. Rules proposed by the EU NIS directive [6] can be applied to identify the most critical infrastructures.

In order to estimate the overall criticality of a load the critical infrastructure it belongs to needs to be identified.

1	Very high effect: The critical infrastructure cannot continue to operate
0.8	High effect: The critical infrastructure can deliver critical products and services by deploying a huge amount of extra resources
0.6	Medium effect: The critical infrastructure can deliver critical products and services by deploying a few extra resources
0.4	Low effect: The critical infrastructure can operate deploying a huge amount of extra resources
0.2	Very low effect: The critical infrastructure can operate deploying a few extra resources
0.0	No effect: The critical infrastructure can operate as normal

Table 4: Infrastructure dependability [5]

Failed CI	Effect on											Overall influence
	Energy	ICT	Water	Food	Health	Financial	Order and safety	Civil admin.	Transport	Chemical and nuclear	Space and research	
Energy	-	0,172	0,266	0,578	0,28	0,534	0,334	0,08	0,48	0,934	0,266	0,39
ICT	0,534	-	0,2	0,334	0,44	0,466	0,534	0,28	0,48	0,534	0,2	0,40
Water	0,166	0,114	-	0,312	0,24	0	0,2	0,12	0,04	0,2	0,134	0,15
Food	0	0,028	0	-	0,12	0	0,066	0,04	0	0,066	0,066	0,04
Health	0,1	0,028	0	0,156	-	0	0,334	0,12	0	0,066	0	0,08
Financial	0,034	0,142	0	0,244	0,04	-	0,066	0	0,12	0,266	0	0,09
Order and safety	0,166	0,086	0,066	0,2	0,2	0,334	-	0,28	0,16	0,2	0	0,17
Civil admin.	0,066	0,172	0	0,076	0,2	0,066	0,2	-	0,04	0,2	0	0,10
Transport	0,234	0,2	0	0,222	0,28	0,2	0,4	0,12	-	0	0	0,17
Chemical and nuclear	0,3	0,058	0	0,044	0,08	0	0,4	0,28	0,04	-	0	0,12
Space and research	0,034	0,114	0	0	0	0	0	0	0,04	0	-	0,02

Table 5: Critical infrastructure dependencies for interruptions for less than two hours [5]

2.7 ESTIMATION OF INFRASTRUCTURE INTERDEPENDENCIES

Figure 3 below shows the estimation of critical infrastructure interdependencies for Austria. This assessment was done by based on expert knowledge and can be used for decision support and electrical load prioritization.

	Kritische Infrastruktur è liefert einen <Auswirkung>-en Service an **Kritische Infrastruktur** ê	Gesundheit	Chemische Industrie	Hilfs- und Einsatzkräfte	Forschungseinrichtung	Finanzen	IKT	Transport und Verkehr	Wasser	Energie	Verfassungsmäßige Einrichtunge	Sozial- und Verteilungssysteme	Lebensmittel		Passive/abhängige Sektoren	Rangreihenfolge
#	Sektor	1	2	3	4	5	6	7	8	9	10	11	12			
1	Gesundheit		4	6	1	3	3	4	4	4	1	4	6		40	1
2	Chemische Industrie	2		3	1	2	4	2	5	6	1	1	2		29	5
3	Hilfs- und Einsatzkräfte (+Pol, BI	5	3		1	2	2	4	2	3	3	3	5		33	3
4	Forschungseinrichtung	1	2	1		2	4	1	1	3	1	1	1		18	12
5	Finanzen	1	1	1	1		6	2	1	5	3	2	1		24	6
6	IKT	1	1	1	1	2		1	2	6	2	1	1		19	10
7	Transport und Verkehr	2	1	3	1	3	3		2	3	2	1	1		22	7
8	Wasser	1	3	2	1	1	3	3		4	1	1	2		22	7
9	Energie	1	1	2	1	2	4	2	2		2	1	1		19	10
10	Verfassungsmäßige Einrichtunge	3	1	2	1	1	4	3	1	2		2	1		21	9
11	Sozial- und Verteilungssysteme	3	2	3	1	2	3	4	3	3	2		4		30	4
12	Lebensmittel	3	4	3	1	4	3	6	6	4	2	2			38	2
	Aktive/verflechtete Sektoren	23	23	27	11	24	39	32	29	43	20	19	25			
	Rangreihenfolge	8	8	5	12	7	2	3	4	1	10	11	6			

Figure 3: Infrastructure interdependencies for Austria

2.8 OVERALL CRITICALITY ESTIMATION

We introduce these precise ratings and associated definitions as a default unspecific to any particular urban environment. It should be part of the collaborative stakeholder process to revise these ratings appropriately to reflect better the precise local topography. Moreover, cities might come up with additional impact factors that need to be incorporated to gain a meaningful criticality assessment for a given city.

In order to obtain an overall criticality rating all ratings are combined in an additive manner. The significance of each rating can further be defined by introducing weighting factor for each rating. The aim of this rating is not to provide an absolute criticality rating but to introduce a metric for relative criticality rating allowing for the prioritization of specific loads depending on their criticality. Undertaking this analysis allows for two deriving appropriate actions in two different ways.

a) The city planner is able to identify regions in a city that are viable for the proper operation of the city. By identifying these regions he is able to do a prioritization of the planning process, e.g. in what region outage response mechanisms need to be implemented first.

b) The analysis enabled the city planner to identify specific loads in a covered region that are allowed to consume more energy than other loads because they are important for the city. The microgrid controller takes into account energy requirements from critical loads that get privileged supply in a way that first all critical loads need to be supplied before least or non-ciritical are supplied.

For estimating the criticality of a specific load or region the following formula applies:

$$C_{load} = Hum * \alpha + Env * \beta + Eco * \chi + Dep * \delta$$

Where C_{load} is the criticality of a load, *Hum* is human consequence, *Env* the environmental consequence, *Eco* the economic consequence, *Dep* the influence of a critical infrastructure on other infrastructures, and α ,. β , χ , δ are the weighting factors of each consequence rating that can be chosen in a way to reflect the considered significance of the individual ratings.

3 APPLICATION

This section considers how the Grid Assessment policy and Criticality Assessment methodology could be applied in practice for decision support focused on city grid resilience. It takes two examples describing current practice for local planning on one hand side and resilience planning on the other hand side.

The IRENE project is focusing on planning for resilience. As described in Section 2.1 above the planning process needs to be initiated by the city planner and should be integrated in the overall process for urban infrastructure planning. The UK local planning process acts as a blueprint for how to integrate the IRENE approach.

Concerning resilience planning we refer to the practices applied in the Netherlands for critical infrastructure protection and their approaches for improving grid resilience using decentralized energy generation.

3.1 UK LOCAL PLANNING SYSTEM

As part of the work undertaken in Task 1.2 we explored the UK Local Planning System. This gave us a context to explore how both this policy and methodology could be applied. While we recognise that the local planning systems in other EU states are not the same as those in the UK the key principles are similar, i.e. that local areas, typically represented by political institutions with democratic mandates, have a voice when considering proposed changes to their build environment. As such we believe it is possible to abstract some key elements of any local planning system concerning how specific types of stakeholders could collaborate when making decisions that impact city energy resilience, the specific focus within IRENE.

While we cannot be prescriptive, this abstraction does allow us to conceptualise a 'Collaborative Framework'. Such a Collaborative Framework describes the means by which key stakeholders within a city could collaborate to help ensure that any changes impacting the power supply to a city have been assessed and optimised for resilience.

In the UK city municipal authorities have the power to place obligations on developers as part of granting planning permission (these are referred to as "Section 106" obligations). This power is typically used to ensure that new developments are effectively integrated into the existing environment, e.g. a new residential development must have a school, shops, suitable road access, affordable housing, etc. Increasingly in the UK this power is also used to ensure that developments addresses local jobs and other community needs.

In principle this political power could be used to help ensure that new developments address municipal energy resilience needs. This establishes a context for energy resilience planning as part of the routine municipal authority planning process; with an instance of the process being triggered by the submission of a planning application from a developer. Figure 3 presents on overview of UK Local Planning System. While today there is no requirement for energy resilience to form part of the Local Plan, it is easy to imagine that with the rise of distributed generators, storage systems and the increased threats involved, resilience planning will become an important part of local planning.

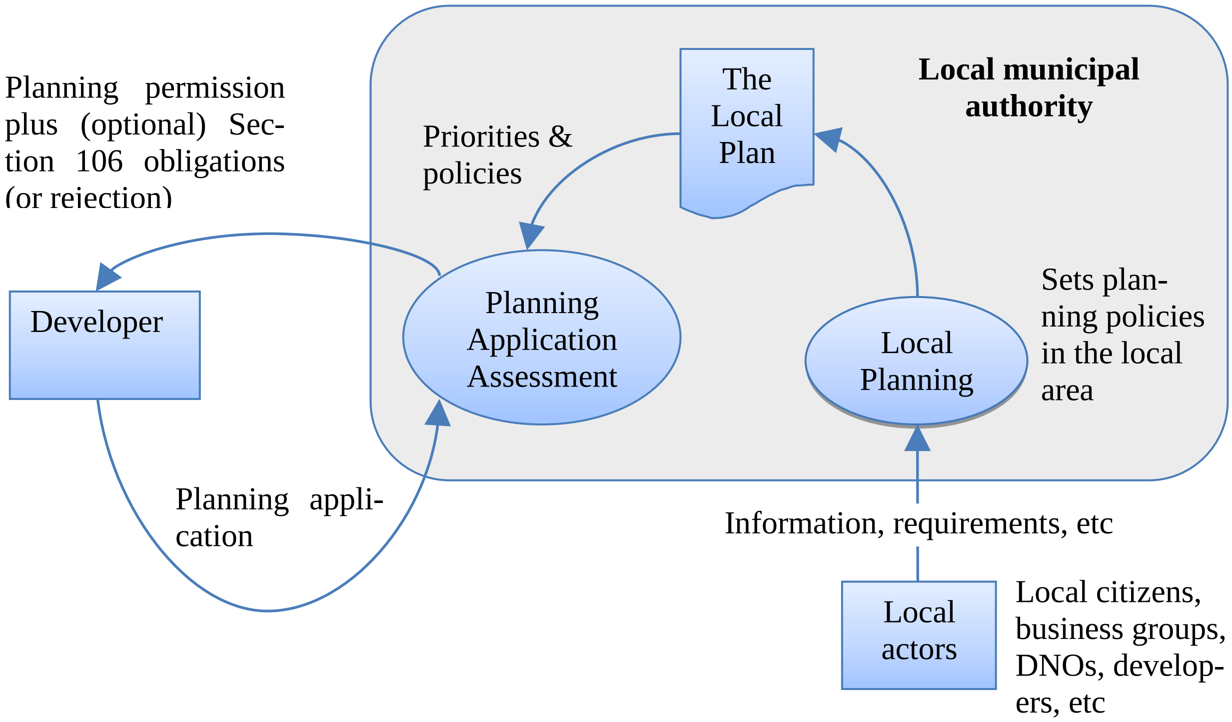

Figure 4: UK Local Planning System

The table below summarises key aspects of the UK Local Planning system assuming it were extended to address energy resilience needs.

Table 6: Key elements of an enhanced planning system

Element	Description
Owner	City Planner role (typically **not** fulfilled by a single person)
Purpose	To identify grid related infrastructure developments that enhance a city's energy resilience and create outline plans, options, needs that will be used to guide individual planning applications forming the basis for Section 106 obligations that will mandate the delivery of grid elements that will specifically enhance energy resilience
Key actors	• City planner role • DNO - explicit knowledge of the current power distribution network Business representative(s) – representing key commercial interests in the local area that will be impacted by local developments (would likely include prospective developers) Citizen representative(s) – representing key community interests that might be impacted by prospective local developments

3.2 Protection of critical infrastructure in the Netherlands

The role of the resilience, as well as its place in planning and decision making processes is not explicitly documented in the Netherlands. Currently, there is no plan to change this in the future. However, at the same time the Netherlands has possibilities to envision significant aspects of future infrastructure planning. These aspects can be related to current practices (that include *Security Regions* within the country) and the ongoing governance experimentation (conducted in the Netherlands under *Exemption Rules).*

Security regions

For the planning in regard to emergencies, 25 security regions (in Dutch: veiligheidsregio's) exist in the Netherlands, as shown in Figure 1. (https://nl.wikipedia.org/wiki/Veiligheidsregio)

Figure 5: Security regions in the Netherlands, Source:[7].

These security regions are in charge of concerns regarding fire brigades, the organization of disaster control and crisis management as well as of the medical assistance organization of the region [10]. The majors of the municipalities inside each security region form the board of this security region.

As regards the tasks of the security regions in regard to protection of critical infrastructure, in practice, they mainly pay attention to the sectors of electricity, portable water, and surface water [11].

Security regions and other stakeholders

Due to the fact that about 80% of critical infrastructure is in hands of companies, close collaboration between security regions and the government and industry is essential for national safety [7]. Therefore, agreements (in Dutch: convenanten) between stakeholders are the preferred policy instrument of the Dutch government [12]. Hereby security regions play an important role and should act as follows: initiating collaboration between critical sectors in the region, initiate contracts and networks, making agreements with operators of critical infrastructure over communication, information and measures, communicating with citizens, coordinating aid to citizens [11].

Collaboration with the NCTV

On the national level, an organization exists for the coordination of fighting terrorism and safety (called Nationaal Coördinator Terrorismebestrijding en Veiligheid, short NCTV). This organization takes charge when pandemics, terrorist attacks, or for example a fall out of the internet or telecommunication network occur [13]. In case of such emergencies, the NCTV works together with the security regions.

The Electricity Grid

The Dutch DSOs are responsible for the safety of all electricity grids. This includes the safety for the surroundings, safety during work activities and the safe use of energy. Of high importance is moreover to prevent, limit and fight disasters concerning the electricity grid [14].

To undertake this latter task, Netbeheer Nederland, the umbrella organization of all Dutch DSOs, signs agreements with the police and the security regions. Until February 2014, agreements have been made with 22 out of the 25 security regions[14]. To give an example, the agreement between security region Brabant-Noord and Netbeheer Nederland concerning gas and electricity was signed by the security region Brabant-Noord, the police of Oost-Brabant, the DSOs Endinet, Enexis, Liander, the TSO (transmission system operator) TenneT and Gasunie [15].

These agreements describe the roles of DSOs and establish how the regional collaboration and information exchange are to take place in regard to disaster control and crisis management. Netbeheer Nederland states that it is especially of importance that in case of an emergency, the electricity and/or gas are temporarily disconnected to prevent worse consequences [16].

To summarize, a wide range of stakeholders are responsible for critical infrastructure in current practice in The Netherlands. With different roles, these stakeholders might consider planning, operational, and recovery aspects related to the grid. Relevant stakeholder therefore might include: municipalities, police, security regions, industry as large consumers, Netbeheer Nederland (electricity and gas DSOs, TSO) and national organizations like the NCTV.

3.3 EXPERIMENTS RELATED TO GOVERNANCE OF DECENTRALIZED, RENEWABLE ELECTRICITY

In addition to considering how resilience in the Netherlands can be imbedded into current governance, it is relevant to account how current experimentations that aim at shaping future governance can account for this aspect. Several of such experiments related to decentralized renewable electricity generation can be found across the Netherlands.

On 1 April 2015, the Crown decree 'Besluit experimenten decentrale duurzame elektriciteitsopwekking'[3] (short: Besluit DDE) was put into effect. In brief, the Besluit DDE grants exemptions to article 16, third paragraph[4] of the Electricity Law, which states that no one can take over the tasks of distribution system operators (DSOs). By lifting this ban, other actors are – under specific conditions – allowed to experiment with the local generation, distribution and sale of renewable energy.

Definition and planned experiments

Exemptions are only granted to associations; meaning owners' associations and energy associations (art. 3). By being in charge of the local project grid, associations take over the responsibilities and in consequence the powers of current DSOs and energy supply companies. The members of the association for example have to finance the project (e.g. purchase technology for electricity generation) and must generate and consume all electricity that is present in the local grid (art. 7). All decision-making power is hence in the hands of associations.

Between 2015 and 2019, each year – based on a tender procedure – 20 projects can be granted an exemption from article 16 of the Electricity Law for a period of ten years. These twenty project exemptions are split into ten 'large grid projects' and ten 'project grids' (art. 1). In a 'large grid project' up to 10.000 entities can be connected to the gird, whereby at least 80% of these entities have to be consumers (the other 20% can be for example be small companies). A 'project grid' is a grid with a maximum of 500 consumers connected to the same regional distribution gird. Overall, the Besluit DDE is mainly intended for the construction of new grids, e.g. when a new neighborhood is being build. In the end, the experiments have to contribute to developments in the area of decentral generation of renewable electricity (or electricity generated via CHP) and decrease the load on the electricity grid through demand side management and consumer involvement (art. 16). This entails that ICT has to be a major component of the local experiments.

Electricity-related requirements to the experiments

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[3] Besluit van 28 februari 2015, houdende het bij wege van experiment afwijken van de Elektriciteitswet 1998 voor decentrale opwekking van duurzame elektriciteit (Besluit experimenten decentrale duurzame elektriciteitsopwekking), Stb 2015, 99.

[4] The tasks of DSOs, as stated in the Electricity Law mainly consist of connecting users to the grid (article 16c), the construction of cross-border electricity grids, and the operation and maintenance of electricity grids (article 15, par. 1).

Associations have to fulfill many requirements before they are allowed to become producer, supplier (formerly: energy company) and system operator (formerly: DSO) of a local grid. These are the standard requirements that apply to DSOs in general: reliability, safety, security of supply, consumer and environmental protection, as well as the technical standards (art. 7). Some of these requirements are however of higher relevance in the experiments, than in the electricity grid outside of these projects.

Security of supply & dependency

Article 7 (para. s) of the Besluit DDE states that associations have to make sure that enough provisions have been made to take care of a shortage or surplus of electricity of the local installations/ for its members. This requirement is especially important when considering that consumers can only consume from the local grid (article 7, para. t). The residents that are connected to such a local project grid are hence entirely dependent on the electricity provided inside this grid. Considering that electricity is a critical infrastructure, the importance of resilience of these local grids is therefore high.

However, resilience is not explicitly mentioned the Besluit DDE.

Governance of resilience

Currently, due to innovative nature of the experiments and the lack of results available to analyses, it is unclear which role resilience plays in the experiments or how it can be governed. At the same time, it can be useful to consider how a more centralized nature of decision making within these experiments can be related to the landscape of stakeholders, who are currently concerned with critical infrastructures.

In its essence, the Crown decree does provide associations with all the decision-making power for its specific local project. Therefore, only one stakeholder can be seen as responsible for topics like deciding on how electricity should be prioritized in case of black-outs. No consultation with other actors is mandatory to take this decision. This might result in easier and faster decision-making, provided that negative outcomes would not strongly interfere with interests of nation-level stakeholders outlined earlier in the document.

From another perspective, associations are entirely responsible themselves for their local grid. Even in case of emergencies no collaboration with other actors like security regions can be directly deduced from existing plans. Because already many requirements are placed on associations, dealing with these apparently unforeseen emergencies rises demands from associations even higher. This is not only a high burden for associations, but also presents a vulnerability for consumers that are connected to a local project grid.

Altogether, due to the mentioned aspects, projects that involve residential areas (e.g. a holiday park) might need to reach out to other stakeholders like security or policy regions to ensure the resilience of these grids. The next subsection briefly reviews four project, three of which include delivering electricity to apartments and holiday homes.

Discussion: Four experiments

As of August 2016, four projects were granted an exemption to start a local experiment (project grid). Two of these projects will take place in individual buildings (project Zwijsen Veghel, project

Black Jack), one project entails the set-up of a solar PV park (project Endona), and the fourth project aims at constructing holiday homes in an recreational area (project Greenparq).

Table 7: Decentralized renewable energy experiments

Project name	**Exemption Holder**	**Stakeholder in the lead**	**Details on the project**	**Technology**
Zwijsen-Veghel	Owners association 'Collegepark Zwijsen Veghel' (founded april 2015)	Project developer Starlight B.V.	Ca. 115 apartments will be build inside a former school complex.	Energy generation (solar PV panels, CHP) Energy management via ICT for residents' appliances Dynamic electricity tariff
Blackjack	Owners association 'VvE-gebouw Black Jack'	JansZon B.V., a supplier and installer of solar PV panels	An apartment complex will be constructed.	Energy generation (214 solar PV panels) Peer-to-peer supply Energy management via ICT
Endona	Energy association 'Endona U.A.' (founded 7 april 2015, preceded by energy association Ecozon). Note: the association's board has as of fall 2015 not yet started to actively attract members.	Energy association Escozon Coöperatie U.A.	The main project is the construction of an 'energy-park', consisting of ca. 7200 solar PV panels.	Energy generation (solar PV panels in energy-park and on residents' roofs) Energy saving via energy management in households Peer-to-peer supply Purchase and sale of renewable energy from a bio-digester
Greenparq	Owners association 'VvE Park Reeuwijkse Plassen' (founded september 2015)	Real estate company D&M Properties (working for investment company GREEN Real Estate B.V., whose subsidiary Green Reeuwijkse Hout B.V. is	Holiday homes will be constructed in an recreational area.	Energy generation (solar PV panels on the roofs of common facilities, CHP) Peer-to-peer supply

		officially leading the project)		

Overall thoughts (no info is available online): While all four projects have to ensure resilience of their critical electricity infrastructure, resilience seems of most importance for project Greenparq. This project will likely not only include electricity infrastructure for residential households, but also involve aspects like neighbourhood safety, telecommunication, water and sewage – vital parts of everyday life which are all related to electricity.

[Gere might be a conclusion on cross-relating current (decentralized) practices and (somewhat centralized) experimentation set-ups]

4 CONCLUSIONS

The project set out to research the concept of a 'collaborative framework' through which a collection of relevant stakeholders could explore and assess the resilience of various grid configuration options.

It was envisaged that this framework would include a collection of policies, tools, resources and methodologies. The policies would provide a set of principles and/or constraints that would guide decision making (who should participate in grid resilience planning, what parameters should be explored, etc.), the tools/resources would facilitate the planning activities while the methodologies would prescribe bodies of practices, rules and procedures for key in resilience planning activities.

In practice we were only partly able to define all different aspects of proposed Collaborative Framework mainly due to the practical difficulties of engaging end users with specific knowledge of current practices and the many variations in these practices across the EU. After talking to numerous city representatives we can conclude that the relevant expertise is rare within city administrations. Within these constraints the project concentrated on a policy that formalised the application of the Open Modelling Framework (described above) and an approach (methodology) for addressing grid component criticality (again as described above).

With the IRENE toolset, collaboration framework and the criticality estimation methodology we provide a whole set of instruments to plan, assess and manage urban energy resilience. The main response mechanism considered and evaluated by IRENE is the local microgrids. The project focused on two scenarios: the grid microgrid with demand side management and reduced upstream grid supply, and the upstream grid outage scenario with no external supply. For the demand side management scenario, load criticality is a mean to differentiate highly critical non-interruptible loads and less critical interruptible loads.

The project also conducted a number of workshops that provided the opportunity to review our approach and specifically to assess the tools, as described in the Open Modelling Framework above, with groups of representative actors/stakeholders. The workshops demonstrated that a collection of relevant actors/stakeholders was necessary to help ensure that options were explored and evaluated. It also clearly demonstrated that there will need to be additional research involving extensive engagement with key stakeholders to fully explore and establish a Collaborative Framework(s) relevant across different EU contexts.

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