



EU-CIRCLE

A pan-European framework
for strengthening Critical
Infrastructure resilience to
climate change

D6.3 Case Study 1 FR Evaluation Report

Contractual Delivery Date: 11/2017

Actual Delivery Date: 01/2018

Type: Report

Version: V0.3

Dissemination Level: Public Deliverable

Statement

The EU-CIRCLE project propose a methodological framework for assessing risk and resilience of climate extreme conditions, climate hazards and climate change scenarios to critical infrastructures and support relative adaptation decisions based on consequences and cost-benefit analysis. This report presents the organization, conduct and lessons learned from the application of this methodological framework to the French case study (CS1).

© Copyright by the **EU-CIRCLE** consortium, 2015-2018

EU-CIRCLE is a project that has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 653824. Please see <http://www.eu-circle.eu/> for more information.

⚠ DISCLAIMER: This document contains material, which is the copyright of EU-CIRCLE consortium members and the European Commission, and may not be reproduced or copied without permission, except as mandated by the European Commission Grant Agreement no. 653824 for reviewing and dissemination purposes.

The information contained in this document is provided by the copyright holders "as is" and any express or implied warranties, including, but not limited to, the implied warranties of merchantability and fitness for a particular purpose are disclaimed. In no event shall the members of the EU-CIRCLE collaboration, including the copyright holders, or the European Commission be liable for any direct, indirect, incidental, special, exemplary, or consequential damages (including, but not limited to, procurement of substitute goods or services; loss of use, data, or profits; or business interruption) however caused and on any theory of liability, whether in contract, strict liability, or tort (including negligence or otherwise) arising in any way out of the use of the information contained in this document, even if advised of the possibility of such damage.



Preparation Slip			
	Name	Partner	Date
From	Frédérique Giroud, Alice Clémenceau, Midori Million, Rachel Jouan and Jean Lecroart	CEREN ARTELIA	12/01/2018
Reviewer	Thanasis Sfetsos	NCSR	15/06/2018
Reviewer			
For delivery	Thanasis Sfetsos	NCSR	

Document Log			
Issue	Date	Comment	Author / Organization
V0.1	15/12/2017	Draft version	Jean Lecroart (Artelia)
V02	15/01/2018	Intermediate version	CEREN
V03	15/09/2018	Final version	CEREN/ARTELIA

List here the changes and their rational
for each release



Executive Summary

The EU-CIRCLE project proposes a methodological framework for assessing risk and resilience of climate extreme conditions, climate hazards and climate change scenarios to critical infrastructures and supports relative adaptation decisions based on consequences and cost-benefit analysis. This report presents the organization, conduction and lessons learned from the application of this methodological framework to the French case study (CS1).

The case study proposes an application of the EU-CIRCLE approach on impacts of heat wave and forest fire impacts on electric and road transport networks, in the Provence-Alpes-Côte d’Azur Region (southern of France). Three operators were involved: RTE (electric transportation network operator), ENEDIS (electric distribution network operator) and ESCOTA (highway network operator).

The tangible results from the final workshop with the operators involved, which are confidential, are presented in the Conduction report [D6.2].



Contents

EXECUTIVE SUMMARY	2
CONTENTS	3
LIST OF ACRONYMS.....	4
1 INTRODUCTION: DESCRIPTION OF FRENCH CASE STUDY (CS1).....	5
1.1 Description of the region.....	5
1.1.1 Administrative borders.....	5
1.1.2 Geography.....	5
1.1.3 Climate.....	6
1.1.4 Vegetation & environment.....	6
1.1.5 Demographics and tourism.....	7
1.1.6 Economic activity	8
1.2 Description of the climate hazard	8
1.3 Description of the Critical Infrastructure.....	8
1.3.1 Electricity.....	8
1.3.2 Transport (highway network)	9
1.3.3 Others	10
1.4 Scenario	10
1.4.1 Rationale for the choice of scenario.....	10
1.4.2 Description of the specific scenario retained	10
2 PLANNING AND ORGANIZATION OF THE CASE STUDY	13
2.1.1 External stakeholders and tools to be involved.....	13
2.1.2 Action plan	14
3 APPLYING THE EU-CIRCLE APPROACH.....	16
3.1 Resilience assessment	16
3.1.1 Filling the end-user questionnaire.....	18
3.1.2 Putting weights to each indicator and resilience capacity.....	19
3.2 Climate analysis	20
3.3 Risk analysis	20
3.4 Adaptation options.....	26
3.4.1 Identify relevant adaptation options to improve the resilience	27
3.4.2 Prioritize the adaptation options identified	28
4 GLOBAL LESSONS LEARNED AND RECOMMENDATIONS	30
4.1 From the operators	30
4.2 From CEREN and Artelia	31
5 REFERENCES	32
5.1 Bibliography.....	32
5.2 Websites	32



List of acronyms

ACRONYM	EXPLANATION
PACA	Provence Alpes Côte d’Azur
EMIZ	Interministerial Defense Zone Head Quarters
SDIS	Fire-fighters and rescue Departmental Service
DREAL	Regional Direction of the equipment and the territorial management
ARS	Health Regional Agency
ONF	National Forest Office

1 Introduction: description of French case study (CS1)

An essential part within the project is to deploy the framework and the modeling platform for concrete case studies. In total five case studies are foreseen, covering various geographical regions and addressing different climate hazards.

One of the case studies is foreseen to be conducted within the Provence-Alpes-Côte d'Azur (PACA) region. This case study is focused on heat wave, dryness and forest fire impacts on three infrastructures: electricity transportation (operator: RTE) and distribution (operator: ENEDIS) networks and an highway (operator: ESCOTA).

1.1 Description of the region

The PACA region under consideration is an area of 31 400 km² with a population of 5 million inhabitants. It is located south-east of France and delineated south by the Mediterranean shore, north by the Alps, east by the Italian Boarder and west by the Rhone valley.

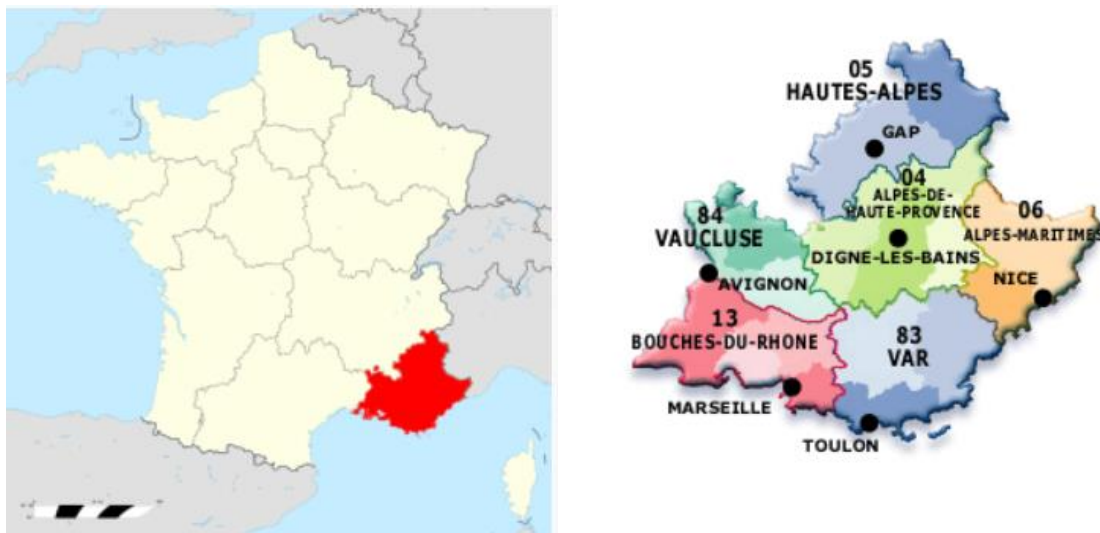


Figure 1 Map of France and PACA region detail

1.1.1 Administrative borders

We suggest to focus the case study on the 3 "departments" (i.e. counties) located along the coast, from west to east:

- Bouches-du-Rhône (with the city of Marseille: 850 000 inhabitants - 2nd most populated city in France)
- Var (with the city of Toulon: 160 000 inhabitants, 15th most populated city in France)
- Alpes-Maritimes (with the city of Nice: 345 000 inhabitants - 5th most populated city in France). it has a boarder with Italy.

1.1.2 Geography

Located between the Alpine range and the Mediterranean sea, Provence-Alpes-Côte d'Azur region is characterized by pronounced contrasts within three main geographical areas:

- The Mediterranean coast is characterized by low shores and cliffs. It shows strong economic and demographic dynamics, in particular in the Bouches-du-Rhône department. The natural reserve of Camargue appears as an exception where human activities remain very limited.

- The center and the western parts are composed of alluvial plains, lowlands and hills. The Rhône and Durance Valleys represent major traffic routes driving a flourishing economy, notably and related to the production of electricity.
- The Provence hinterland and the Alpine range (located north – east of the Region) is a sparsely populated area. The decline of agriculture enables forest to grow and the development of peri-urbanization.

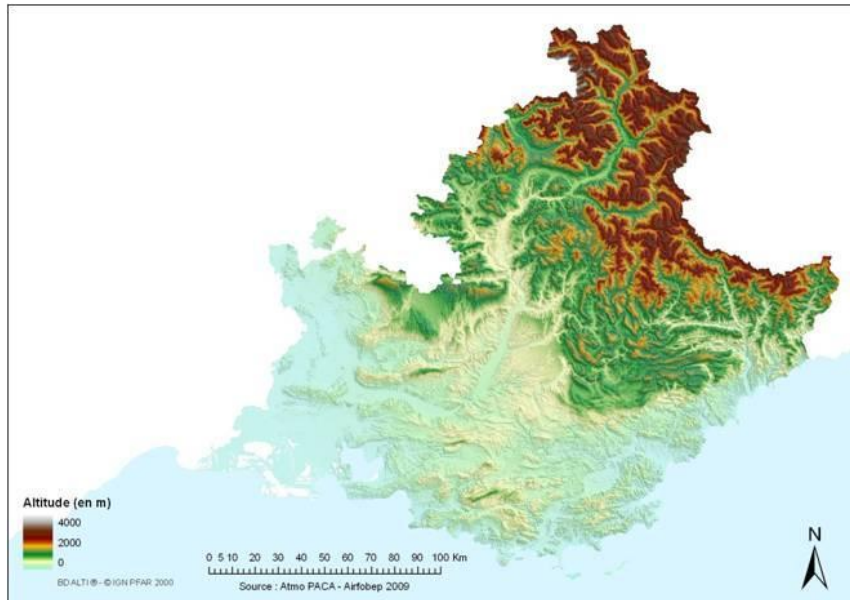


Figure 2: Topography of the region (source: Energ'air)

1.1.3 Climate

It has a Mediterranean climate characterized by abundant sunshine, warm and dry summers and mild and humid winters, with erratic rains and strong winds (Mistral, Tramontane, Lombarde), which makes this region a fire prone area.

Two main climate zones can be distinguished within the Region, the sea-shore sunnier and warmer, and the mountainous hinterland with harsher winters.

1.1.4 Vegetation & environment

The vegetation type in this region is a sclerophyllous forest ecosystem. It is characterized by low height and low density, not very green flora. It has two main types of vegetation cover:

- tree stratum: holm oaks, cork oaks, pine trees, chestnut trees, olive trees.
- shrub stratum: heaths, rosemary, lavender, juniper.



Valuable and threatened species and habitats are present in the region and therefore, an important number of Natura 2000 sites (natural reserves) are located in PACA region, as shown in the map below.

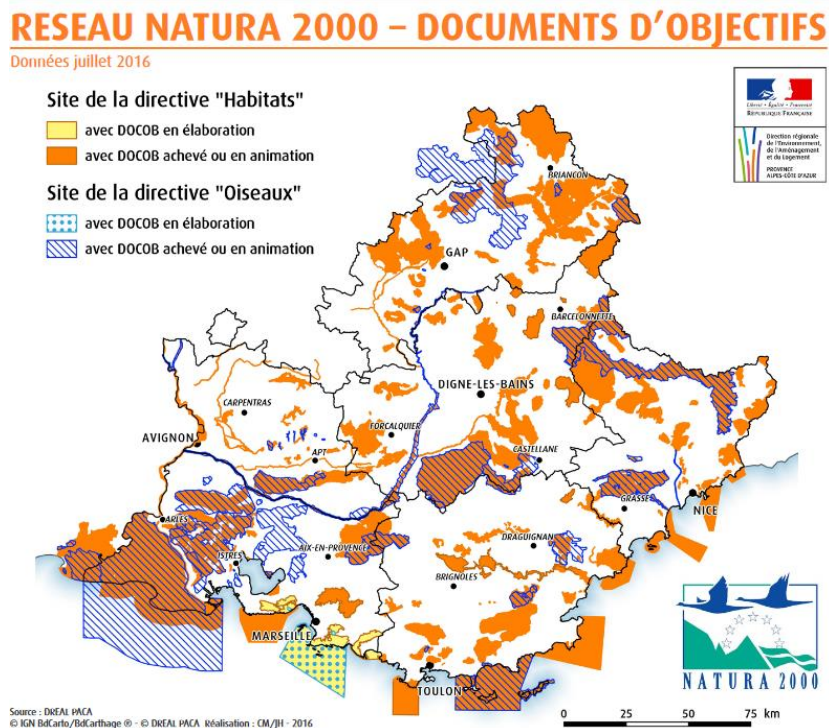


Figure 3: Natura 2000 network in PACA (source: DREAL PACA)

1.1.5 Demographics and tourism

With 4.9 million inhabitants (2014), the Region is the third of the country in terms of population and appears as one of the most attractive regions (10% of the population has been living in the Region for less than five years). However, it is expected that the average age of the population (since one third of the population being over 60 years old). The population is not spread heavenly on the territory, 73% leaves less than 20 kms away from the sea shore.

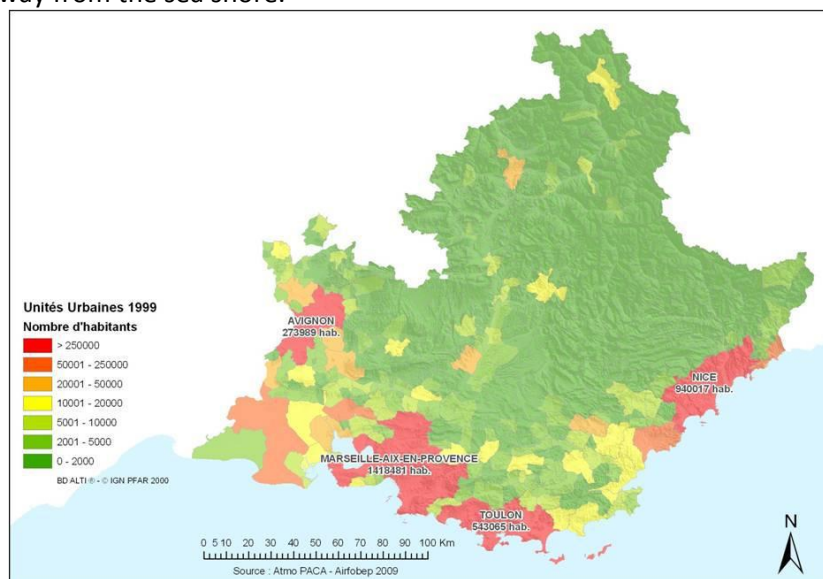
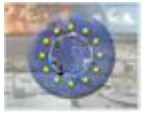


Figure 4: Urban areas of PACA (Source: INSEE, 2007)

Over 31 million tourists are hosted every year in the region. This region is the first destination for domestic tourism and 20% of the tourists are foreigners. Tourism represents 11% of the regional GDP and 120 000 jobs in the PACA region. Tourism is most important in spring and especially summer on the sea shore.



1.1.6 Economic activity

Provence-Alpes-Côte d'Azur Region is responsible for around 7% of the national growth. Tertiary activities and services (both public and private) account for 80% of the added value and paid employment. Industry ranks second representing 11% of the regional added value (figures from 2006). Since 2008, the economic crisis has had a particularly strong impact on the employment in the region. The unemployment rate indeed exceeds 11%¹ (January 2017) while the national average is 9.7%ⁱ.

1.2 Description of the climate hazard

The climate hazard under scrutiny in this case study is a heat wave induced forest fire.

The French official definition of "canicule" (*i.e.* severe heat wave) is adapted county by county (*i.e.* département) and can be summed up as below²:

During at least 3 full days:

- the minimum temperatures (at night) shall not be lower than 24°C (Bouches-du-Rhône and Alpes-Maritimes) or 23°C (Var);
- the maximum temperatures shall exceed 35°C (Bouches-du-Rhône and Var) or 31°C (Alpes-Maritimes).

This specific hazard was chosen because the French experts from the various fields concerned (climate research, weather forecast, public policy, forestry, etc)³ make the hypothesis that forest fires will increase in the coming years as a consequence of climate change (temperatures rise). There are numerous remaining uncertainties, yet this hypothesis is coherent with the evolution already observed and recorded. Public expenditures are increasing in the field of fire fighting in France. Even though the hazard and its impacts are considered to be on the rise, the collateral damages are expected to be less severe.

According to French experts⁴ in forest management, a 20 years time-horizon is very short in terms of vegetation evolution. After analysis, changes in the vegetation cover do not appear to be significant enough to be taken into account in the scenario since:

- Forestry is not very profitable in the Mediterranean area and there are not a lot of investment foreseen in this domain
- Forest fires are already prevalent
- Decline in some species is possible but unlikely to play a significant role on the forest fire hazard in such a short time frame.

It is therefore suggested to stick to the existing vegetation covers in the model.

1.3 Description of the Critical Infrastructure

1.3.1 Electricity

The French case study will focus on the electricity network, from production/generation to distribution to the end-user customers, including transmission. Several Critical Infrastructure operators are involved to run this network. Two of them appear as key players for this case study: RTE (transmission) and ENEDIS (distribution to end-users). They shall all be involved at the various stages of the study. However, for this case study, the transmission network is considered the backbone of the electricity network (as it will be the most affected by the specific scenario).

¹ DIRRECTE PACA

² Source: INVS

³ Rapport de la mission interministérielle Changement climatique et extension des zones sensibles aux feux de forêts, Juillet 2010.

⁴ JL Peyron, Director of GIP Ecofor

The transmission network operated by RTE in PACA covers 5662 km of aerial transmission lines and 595 km of underground transmission lines. 200 substations are installed, providing a transformation capacity of 17833 MVA.⁵

In terms of power transmitted through the network, PACA consumes around 37 GWh per year (figures of 2015) while it produces around 12 GWh. The power demand (higher and lower peaks in 2015) varies between 2836 MW and 8006 MW in the region.

The main assets that will be investigated for this CI are: production units (power plants), transmission and distribution lines (both aerial and buried), substations, and control center.

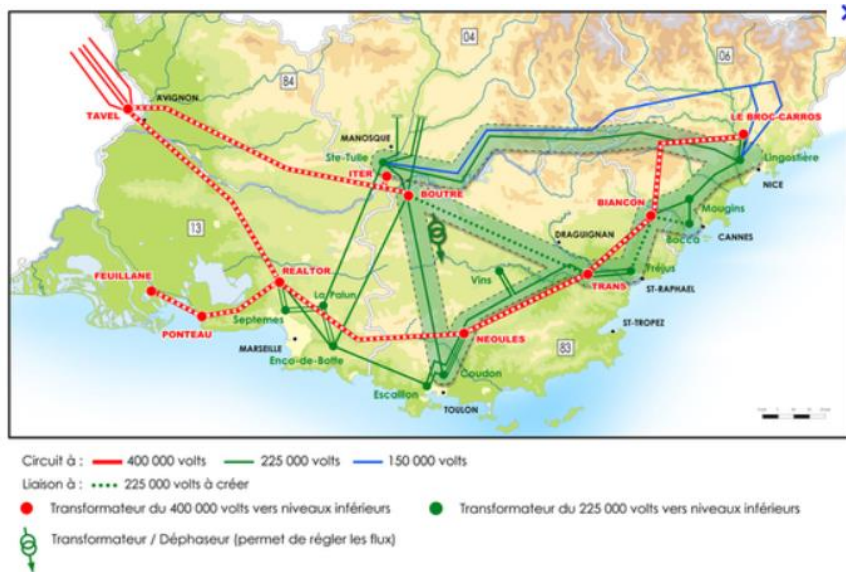


Figure 5: Electricity transmission network (high tension)

1.3.2 Transport (highway network)

The highway network also appears as one of the CI most affected by the forest fires risk. It is also relying on the electricity provision for delivering its services.

In the PACA region, and in particular in the three departments under scrutiny, the main highway operator is ESCOTA. It operates a network of 459 kilometers under the status of service concession until 2032.

The main assets that will be investigated for this CI are: roadways, safety related systems, traffic control center, rest and service areas.

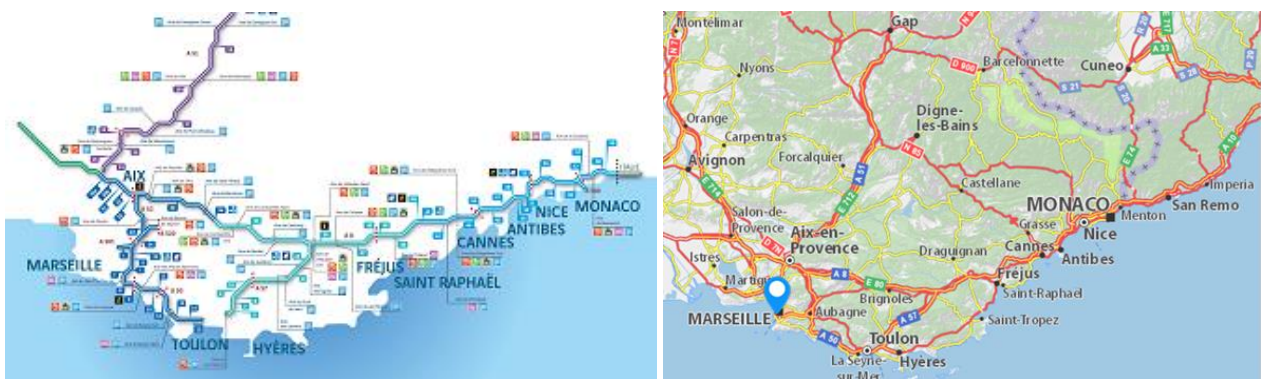


Figure 6: Highway network operated by ESCOTA

⁵ Schéma décennal de développement du réseau 2016, Perspectives en Provence-Alpes-Côte d'Azur, Janvier 2017.



1.3.3 Others

Civil protection

The Public Authorities in charge of the civil protection (fire fighters) are also considered as a Critical Infrastructure in EU CIRCLE and will therefore be treated as such.

The main assets that will be investigated for this CI are: terrestrial and aerial means of intervention, water network, command and control centers.

Industries

Besides the highway network, cascading effects of electrical incidents due to heat wave and forest fire on industrial plants (located in Fos, west of Marseille) may be considered as well.

1.4 Scenario

1.4.1 Rationale for the choice of scenario

As described in the first section of this document, the PACA region is constrained by the specific topographic relief. This has consequences on the organization of the networks under consideration for this case study.

Indeed, in terms of transportation, the main axis is east-west oriented. This is the only one besides secondary road networks serving the eastern part of the region.

Regarding the electricity network, the unbalance is even more obvious. In 2015, PACA region produced 41% of the electricity that was consumed in the region. It therefore had to import almost 25GWh this same year, mainly from the nuclear power plants located in the Rhone Valley. 64% of the electricity production in the region comes from renewable sources, mainly hydropower (Durance and Verdon valleys mainly, Nice hinterland to a lesser extent).⁶ The generation of electricity in PACA is mainly located in the mountainous hinterland, and the importation comes from the Rhône Valley, while the consumption occurs on the seashore.

It creates a situation of electricity peninsula where the eastern part of the region is heavily relying on one main transmission line. In 2015, works were carried out to develop missing links and alternative paths in the network by installing a high tension buried line north of the Var department. However, it is already considered that this solution may not be sufficient to ensure a robust network after 2025. Indeed, RTE plans that the electricity consumption will increase in the region by around 15% by 2030⁷. It is also considered that seasonal patterns with stronger peaks are to be expected, linked to warmer summers and more frequent heat waves. The injection of more and more electricity from intermittent renewable sources into the network (related to emissions reduction plans) may also weaken the network, since power storage solutions are not yet mature.

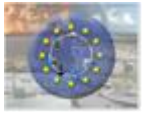
1.4.2 Description of the specific scenario retained

A heat wave has been striking the south-east of France for a couple of days, causing incidents on the electricity network (temperature alerts reached in some substations) and on the roadway (behaviour changes caused by stress). The forest fire risk index is extremely high, especially in the Var department.

A forest fire ignites north of the city of Brignoles and is pushed south-west by the wind. Soon, the fire reaches both the highway (A8) used by thousands of tourists in summer time. Due to the important smoke production, visibility is significantly reduced so that highway has to be closed, resulting in an important traffic increase on the secondary road networks. Tourists are confined on highway rest and service areas,

⁶ Schéma décennal de développement du réseau 2016, Perspectives en Provence-Alpes-Côte d'Azur, Janvier 2017.

⁷ Schéma Régional Climat Air Energie PACA, Juin 2013.



while basic services delivery (Drinking water, road signalling, radio emission, etc) is threatened. Additional accidents are caused because of the panic of people.

Because of the risk of electrical priming caused by smoke, as well as to facilitate aerial firefighting operations, electricity lines are cut off, and in particular extra high aerial lines serving the eastern part of the region (400kV and 2325kV). Load-shedding plans have to be applied.

Because of the high temperature of soil and ground, a junction box of the buried extra high tension line crossing the north of the Var department stops functioning, cutting this line as well.

The risk of a black out in the eastern part of the region is extremely high, given that the two main power transmission lines are cut. The impact on the general public and on the other CIs (in particular the highway network) may be very severe.

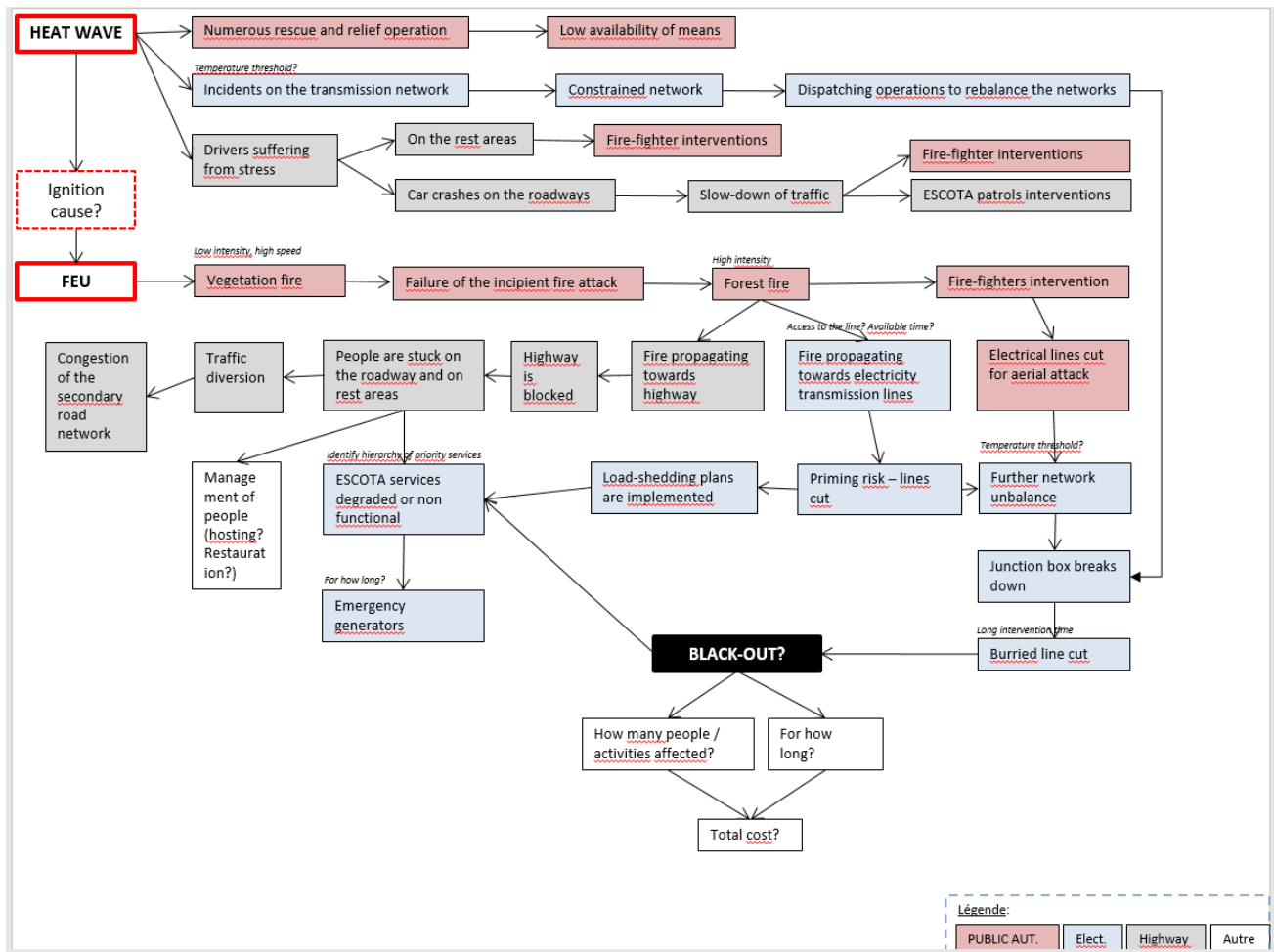
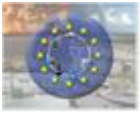
Other emergency operations are disturbed because of the large delay of alert, decrease of available means and major dispersion of such means.

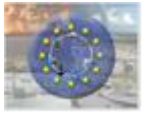
The case study occurs during the summer, when the population highly increases due to the tourist presence, resulting in an overloaded flux of people on the highways networks and increasing the consumption of electricity. Moreover, with the presence of tourists during this high risk period, the fire ignition probability increases too.

In recent years, there have been repeatedly incidents where many dwellings lost electricity, e.g.:

- May 2005: 1 500 000
- July 2009: 1 200 000
- December 2009: 2 100 000

The case study scenario, validated by critical infrastructure operators is based on the following scheme:





2 Planning and organization of the case study

2.1.1 External stakeholders and tools to be involved

Heat wave and forest fires management involve many organizations interactions in order to protect people, goods and to ensure activity continuity services as electricity furniture and road network use.

In order to reach the case study 1 workshop event, several steps were required.

Numerous meetings were organized with the critical infrastructure operators, RTE, ENEDIS and ESCOTA. The objectives were the following:

- Define the assets of their respective networks;
- Define the damage functions for each asset;
- Collect the current procedures dealing with prevention, planning and management;
- Collect data concerning previous events which impacted their respective networks;
- Collect information on their activity continuity plans;
- Validate with them the proposed scenario.

The acquisition of those information allowed to collect input data for the elaboration of the RAT tool and the CIRP platform

Following the meetings with the Critical Infrastructure Operators concerning the specific subject of heat wave and forest fire, it has been concluded from our part that there is a lack of exchange between the concerned involved organizations and operators. The fact is that currently, there are no planning tools allowing scenario development, analyzing resilience of their network, defining interactions between critical operator's facilities and determining the impacts of the various hazards on the infrastructure assets. Moreover the topic of climate change is only partially analyzed in each operator prevention plan, and the actions to be undertaken between each involved entity are not clearly defined.

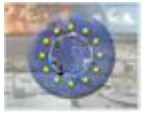
They are working together only during crisis situation and not for planning purposes. They prepare themselves for crisis situation through crisis management exercises that occur every 2 years, organized by the zonal prefecture. The general objective of such exercise is to test the coordination and the information transmission capabilities between public actors and critical operators in case of failure or major impacts of the various networks. The limits of such exercises are:

- the realization of a single scenario during one or few days.
- the various organizations work together only for crisis management situation

To perform the study case 1 and to raise awareness of our involved critical operators, it has been decided, before organizing the study case 1 workshop, to organize a crisis exercise (with which they are used to) and to ingest the Eu-CIRCLE topics

For this exercise, the involved actors are the following:

- Public authorities: zonal prefect (deployment of aerial means for fire-fighting), prefect (decision to cut the electric lines)
- Firefighters units: SDIS13, SDIS 83
- Coordination center: EMIZ
- Police/gendarmerie forces
- CI representatives: RTE, Escota, France Telecom, SNCF,
- Public entities in charge of territorial resilience: DREAL, ARS



- Meteo France as data providers (heatwave/dryness characterization)
- ONF as data provider (vegetation dryness situation)

The global objective of the exercises are the following:

- To raise awareness of vulnerabilities and interdependencies networks;
- To analyze the impacts of network failures and develop the corresponding countermeasures;
- To raise awareness of climate change impacts;
- To allow the associated players to test their respective internal tools;
- To test the sharing of crisis management tools.

2.1.2 Action plan

Our action plan was driven by the organization of 2 events: the real crisis management exercise and the case study1 workshop. To reach both objectives, the following steps occurred:

- table top exercise took place on 4th of April: the objective was to check, only with the critical infrastructure operators, that the whole planned actions to run the predefined scenario could be covered during the workshop study case with the various developed tools.
- Organization of 2 meetings to decide the real crisis management scenario between all involved entities.

The crisis management exercise occurred on the 19th October : The interest was to understand, when an event occurs, how the various organizations are working together and how they apprehend the interconnection between the entities in their decision, the actions made during prevention planning, their knowledge about the way of working of the other operators.

It has been very instructive to see that the coordination between various teams is complicated and not well organized. The main reason is that they do not take the time to work all together in order to plan the various actions and decisions, as no tool exist currently to help them. They have no common GIS tool, no hazard simulators, no data concerning other critical infrastructures. It has been clearly shown that they communicate between them only by phone and that the common interlocutor is the rescue forces or the prefect authorities. Even if this behavior during a crisis management is completely conducted by the vertical French scheme coordination and procedures, it is obvious that there is a lack of those teams preparation and that they do not plan at all climate change impact on the interconnected infrastructure.

After this exercise, the features of the CIRP tool have been refined in order to present them during the case study 1 workshop.

The case study 1 workshop was organized on 7th of December; the conduction of this workshop is described in the D6.2 document.

The summary of the various actions undertaken to reach case study 1 is presented in the following table.



#	Description	Time
1	Meet with CI operators,	M21 (Feb)
	Describe assets	
	Elicit damage functions for each asset	
	Identify thresholds	
	Describe network	
	Assess the network properties affected by climate change (supply and demand)	
	Identify interdependencies	
2	Collect all the necessary data sets	M21 (Feb)
	Decide on time series to take into account in the data sets	
	Hazard (IFM projections, ONF for vegetation, etc)	
	Run fire propagation models	
	Flows (ask network operators: traffic on highway during peak season models, energy demand and supply models in our case)	
3	Provide all data sets in the right format to the CIRP	M22 (March)
	Organize a discussion with CIRP developers to check the format	
4	Use the network builder	M22 (Mar)
	Represent the network as formalized in EU circle	
	Understand the network dynamics and represent them in the scheme	
	Decide on the discretization of time for the scenario elaboration	
5	Assess impacts	M22 (Mar)
	Describe direct impact(s) for each asset	
	Establish the list of indicators for measuring direct impact	
	Describe indirect impact(s) for each asset	
	Establish the list of indicators for measuring indirect impact	
	Discuss with CI operators adaptation measures	
	Discuss how impact assessments should be formalized in the CIRP	
6	Dry run with end-users (table top exercise in Valabre)	4th Apr.
	Mobilise CI operators and firefighter's authorities	
7	Complete asset & network information	M23 (Apr)
	Add missing assets (using D3.1-M22)	
	Complete interdependencies if necessary	
	Modify damage functions, thresholds and network properties if necessary	
8	Validate network description	M23 (Apr)
	Add nodes and flows to the scheme if necessary	
9	Validate impact assessment method	M24 (May)
	Identification of new kinds of impacts	
	Validation of indicators, specification or definition of new indicators if necessary (integrate D4.4-M24 outputs)	
10	Meeting with operators for the crisis management exercise	M25 (June)
	Refine scenario for crisis management exercise	
11	Execution of the crisis management exercise	M29 (19 th of October)
	Mobilise CI operators and Public authorities	
12	Validation for Case study execution	M29 (Oct)
	Logistics preparation for Case Study Execution	
13	Integration of the whole data/models results in CIRP platform	M30 (November)
14	Execution of Case Study	M31 (7 th december)
	Mobilise CI operators and Public authorities	
	Presentation of the RAT tool and CIRP platform	
	Run evaluation using the validation protocol (D6.1 - M27)	
15	Report results	M 33 (Feb)
	Collect all necessary data (external experts responses to evaluation)	
	Analyze the data	
	Produce the results (risk analysis of CI under climate change conditions)	
	Write the report	

3 Applying the EU-CIRCLE approach

The EU-CIRCLE approach application to the French case study was conducted following three steps:

1. The resilience assessment of each infrastructure, to identify the available potentials to improve the resilience. This analysis was conducted using the Resilience Assessment Tool (RAT), provided under the Tasks 4.1 and 4.3 (CI Resilience Framework and CI Resilience Indicators). This tool wasn't yet included in the CIRP for this case study.
2. The risk analysis, to identify the critical points of the interconnected infrastructures regarding heatwaves and forest fires (in the climate change context). This step was deployed using various CIRP analysis developed under the Work Packages 2 (Climatic Data Capture and Processing) 3 (Critical Infrastructure Risk Model for Climate Hazards) and 5 (Development of EU-CIRCLE Framework); according with the scenario described above (1.4).
3. The identification of relevant adaptation options (according to the possible resilience improvement) and its prioritization, to first improve the resilience of the most critical assets. The final version of the adaptation framework, developed under the Task 4.4, wasn't yet available for this case study. However, the available material (adaptation option template and guidelines from the D4.6 first version) allowed conducting this analysis. An evaluation of the adaptation options impact on the resilience was conducted using the RAT, to visualize the infrastructures resilience improvement.

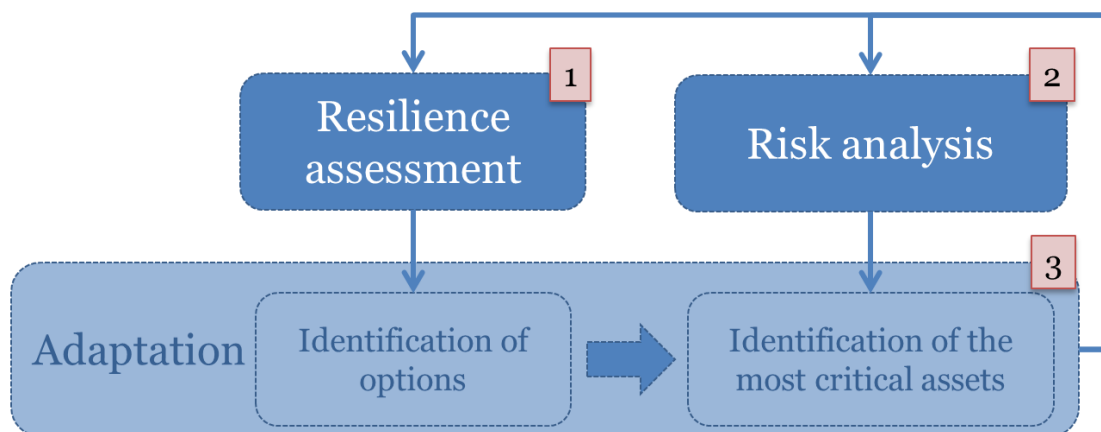


Figure 7: Application of the EU-CIRCLE approach in three steps

3.1 Resilience assessment

The CI operators involved in the case study 1 are not familiar with the concept of resilience, unlike the risk or hazards prevention ones. Before any specific analysis and application of EU-CIRCLE tool, it was necessary to proceed to a global training course on this broad concept to explain:

- The holistic approach inherent to this concept, which encompasses risk prevention, crisis management, physical and functional resistance of an infrastructure to an event, etc. ;



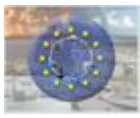
- The EU-CIRCLE overall approach, with five resilience capacities.

EU-CIRCLE resilience capacities [D4.5]	
Resilience capacities	Definition
Anticipatory capacity	The ability of a system to anticipate and reduce the impact of climate variability and extremes through preparedness and planning (Bahadur et al., 2015). This is considered as a proactive action before a foreseen event to avoid disturbance, either by avoiding or reducing exposure or by minimising vulnerability to specific hazards (Kellett and Peters, 2014). As such it has close links to vulnerability, hazards and prevention.
Absorptive capacity	The ability of a system to buffer, bear and endure the impacts of climate extremes in the short term and avoid collapse (death, debilitation and destruction of livelihoods) (Blaikie et al., 2003; Folke et al., 2010, Bene, 2012). This is the first line of defence (Biringer et al., 2013).
Coping capacity	The ability of people, organizations and systems, using available skills and resources, to face and manage adverse conditions, emergencies or disasters (UNISDR, 2009). This is similar to absorptive capacity. The absorptive is immediately after a disaster whereas coping can be for a comparatively longer period.
Restorative capacity	The ability of a system to be repaired easily and efficiently (Biringer et al., 2013). This capacity is associated with recovery too. In the context of critical infrastructure, system repair is the distinguishing feature of restorative capacity and it has been claimed as the final line of defense that requires the greatest amount of effort. Biringer et al., 2013 state that restorative capacity is not usually used unless either the absorptive and adaptive capacities are not able maintain an acceptable level of performance or the system is completely broken and unable to perform.
Adaptive capacity	The combination of assets, skills, technologies and confidence to make changes and adapt effectively to the challenges posed by long term trends, such as future climate change (UNISDR, 2009). One of the distinguishing features of this capacity is the reorganization and change of standard operating procedures where Biringer et al., 2013 claim this as the second line of defense.

For training course needs and operators better understanding, each resilience capacity was presented with concrete examples and illustrations.



Figure 8: illustration of equipment and procedure for forest fires mitigation, regarding the anticipation capacity



Once the operators became aware of the concept and its meaning in the EU-CIRCLE approach, it became possible to present and work with the Resilience Assessment Tool (RAT) itself, future module of the CIRP. The training took place the RAT logical, in two stages:

The Resilience Assessment Tool (RAT), provided under the Tasks 4.1 and 4.3 (CI Resilience Framework and CI Resilience Indicators) was developed only for the asset level and wasn't yet included in the CIRP for this case study. At the end of the EU-CIRCLE project, two more scales will be available and included in the CIRP for the resilience assessment: the infrastructure and the network of infrastructures ones.

For the case study needs – test and training – the operators worked on one type of asset by infrastructure (transmission line for the electric transport and distribution networks; road for the highway).

N.B.: most resilience indicators used for the asset scale approach are relevant for the infrastructure scale approach.

3.1.1 Filling the end-user questionnaire

After a presentation of the RAT, the operators were firstly invited to appropriate the end-user questionnaire. This Excel tab will be the main interface of the resilience framework in the CIRP. It aims to collect the input data available to qualify the resilience, regarding the five capacities.

This questionnaire was designed to be used for any type of infrastructure in Europe. It is therefore very generic. As presented below, it was necessary to explain and justify each response with concrete data.

During the case study course, this questionnaire was prefilled with data collected from the operators (interviews in 2016, Tabletop Exercise in April, etc.). When data were not available from the operators (mainly for confidential reasons), Artelia team set up assumptions based on additional research: this was especially the case for the estimation of costs. The final workshop allows the operators to revise the prefilled questionnaire, complete and correct the responses according to their knowledge and comprehension of the tool.

	A	B	C	D	E	F
1	ITEM	RESILIENCE CATEGORIES / SUBCATEGORIES			VALUE	UNIT
2						
54	ABSORPTION					
55	10.	Acceptable time that CI is not able to serve its intended function			3	Minute
56	11.	Acceptable costs of asset damage			1500	EUR/m
57	12.	Safety design standards for respective hazards are applied			yes	
58		If yes:				
59	12.1.	How many relevant standards exist		2		
60	12.2.	How many relevant standards is applied		2		
61	12.3.	How many climate related hazards (defined in scenario) applied standards covered		0		
62	13.	Regular maintenance of the asset is performed			yes	
63		If yes:				
64	13.1.	Maintenance plan exist		yes		
65	13.2.	Maintenance is performed according to the plan		yes		
66	13.3.	Critical infrastructure is fully operational		yes		
67	14.	Asset backup exist			yes	
68		If yes:				
69	14.1.	Acceptable time for which is backup available (start of backup)			5	Day
70	14.2.	Acceptable time in which is backup available (duration of backup)			60	Day
71	COPING					
72	15.	Acceptable time for response			12	Hour
73	16.	Emergency plans under Climate Hazards (in the context of climate change) exist			yes	
74		If yes:				
75	16.1.	Plans are up to date		yes		
76	16.2.	How many climate related hazards (defined in scenario) it covers		0		
77	17.	Business continuity plans under Climate Hazards (in the context of climate change) exist			yes	

Example of objectivation

RTE applique un cycle de maintenance préventive, dans le cadre duquel chaque asset est visité au moins une fois par an.

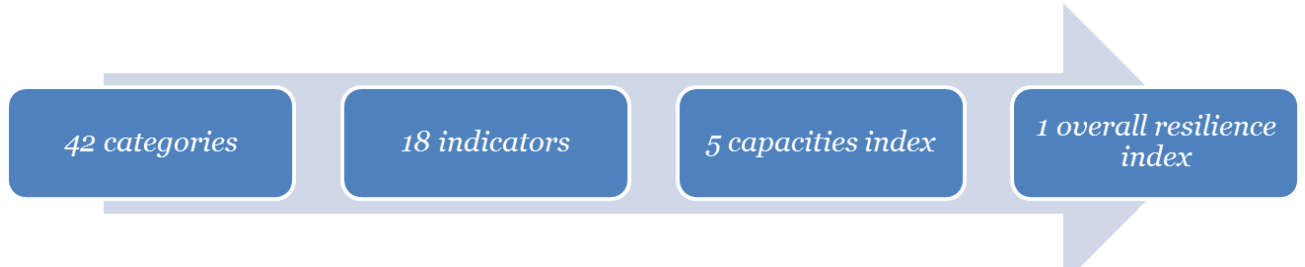
Fields to be completed

Example of objectivation

Fields to be completed

3.1.2 Putting weights to each indicator and resilience capacity

The information collected in the end-user questionnaire is automatically used by the RAT to measure forty two categories aggregated in eighteen indicators, themselves aggregated to measure five resilience capacities index (figure 10), themselves aggregated to measure an overall resilience index (figure 11).



This logical process is influenced by the end-user, who had to prioritize the categories for each indicator, the indicators for each capacity and the capacities for the overall resilience.

During the case study final workshop, each operator was invited to prioritize these issues (categories, indicators and capacities), according to the relative importance of each ones (from the operator point of view).

Coping index 4,55

Resilience Indicators	Resilience Categories / Subcategories	Subcategories index i	Resilience subindex I	Weight I	Real I	Resilience index R	Weight R	Real R
3.1. Response	3.1.1. Time needed to response		6,67	2	2,20	5,50	2	1,82
	3.1.2. Emergency plans under Climate Hazards (in the context of climate change) exists		5,00	2	1,65			
	3.1.2.1. Plans are up to date	10,00						
	3.1.2.2. How many climate related hazards it	0,00						
	3.1.3. Business continuity plans under Climate Hazards (in the context of climate change) exists		5,00	2	1,65			
	3.1.3.1. Plans are up to date	10,00						
3.2. Economics of response	3.2.1. Cost of response (for CI only)		5,00	1	5,00	5,00	2	1,65
	3.2.2. Backup cost		n/a	n/a	n/a			
3.3. Interoperability with public sector	3.3.1. Procedures exist		10,00	2	3,30	3,30	2	1,09
	3.3.2. Communication system exist		0,00	2	0,00			
	3.3.3. Joint action plans exist							
	3.3.3.1. Plans are tested	0,00	0,00	2	0,00			
	3.3.3.2. Plans are up to date	0,00						

Indicators and categories Outputs from end-user questionnaire and from the scenario (RAT) Category weighting Indicator weighting

Figure 10: Screenshot of a capacity index worksheet (RAT)

Overall resilience index = 4,30

Resilience Indicators	Resilience index R	Capacity index C	Weight C	Real C
Anticipation				
1.1. Awareness of potential hazards	0,50	4,30	3	0,86
1.2. Quality/extent of mitigating features	0,80			
1.3. Quality of disturbance planning/response	1,33			
1.4. Communication Systems / Information sharing	0,66			
1.5. Learnability / Training	1,00			
Absorption				
2.1. System failure (integrity of CI affected)	2,02	4,91	3	0,98
2.2. Severity of failure (services of the CI affected)	1,20			
2.3. Resistance	1,68			
2.4. Robustness and redundancy	0,00			
Coping				
3.1. Response	1,82	4,55	3	0,91
3.2. Economics of response	1,65			
3.3. Interoperability with public sector	1,09			
Restoration				
4.1. Post-event damage assessment	1,70	6,11	3	1,22
4.2. Recovery time	1,11			
4.3. Economics of restoration	3,30			
Adaptation				
5.1. Adaptability and flexibility	1,63	1,63	3	0,33
5.2. Impact / consequences reducing availability	0,00			
5.3. Economics of adaptation	0,00			

Resilience capacities weighting

Overall Resilience

Anticipation

Adaptation

Absorption

Restoration

Coping

Figure 11: Screenshot of the overall resilience index worksheet (RAT)

3.2 Climate analysis

The evolution of critical meteorological parameters was calculated for 2006-2015 and 2036-2045 periods with climate scenario: RCP4.5 and RCP8.5. A data set was provided on the concerned PACA area and was integrated in the CIRP tool allowing to perform an analysis of extreme values and return periods and probability of exceedance. The main objective of such a tool is mainly to analyze the evolution of fire season duration, to assess the heat wave period evolution and to study the probabilities of having extreme values during 2036-2045. In this scenario (heat wave and forest fires), the proposed extreme parameters to analyze are maximum daily temperature, maximum daily wind and daily rain, during the forest fire period (First of May to end of October).

3.3 Risk analysis

This is performed through the use of the following tools:

- G-FMIS_FWI tool has been used to estimate Fire Weather Index (FWI), Drought Code (DC) and Fine Fuel Moisture Code (FFMC), daily maps using the FWI Canadian System Equations. Those parameters were evaluated using climate data coming from the previous defined climate scenario.

For example, the following FWI values obtained for the PACA area were integrated in CIRP platform:

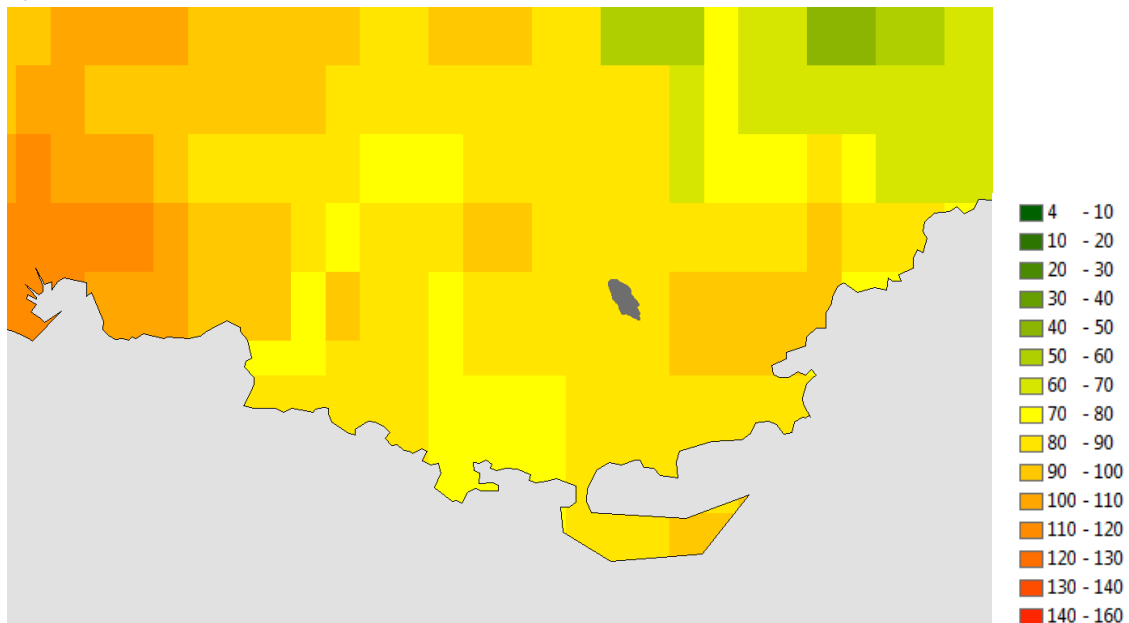


Figure 12 Climatic model MPI / RCP85/max FWI: period: 2006-2015

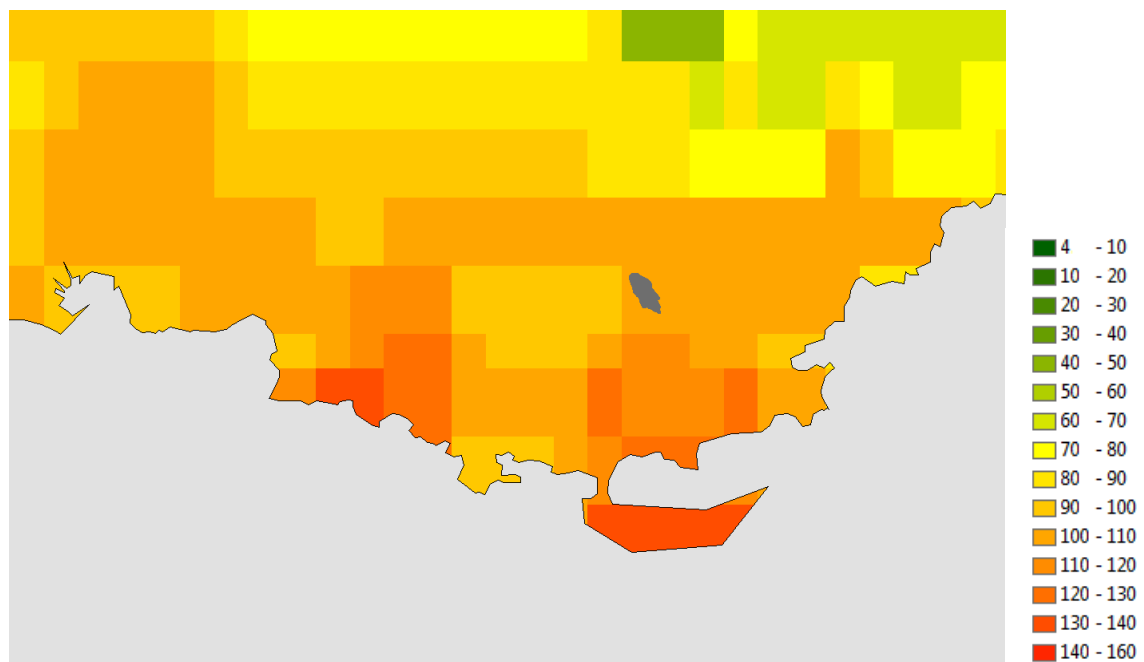


Figure 13: Climatic model MPI / RCP85/ max FWI: period: 2036-2045

From this result, practitioners who participated in the project life asked to have specific values such as the number of days for which the FWI should be greater than 50 for the same periods and the whole PACA area:

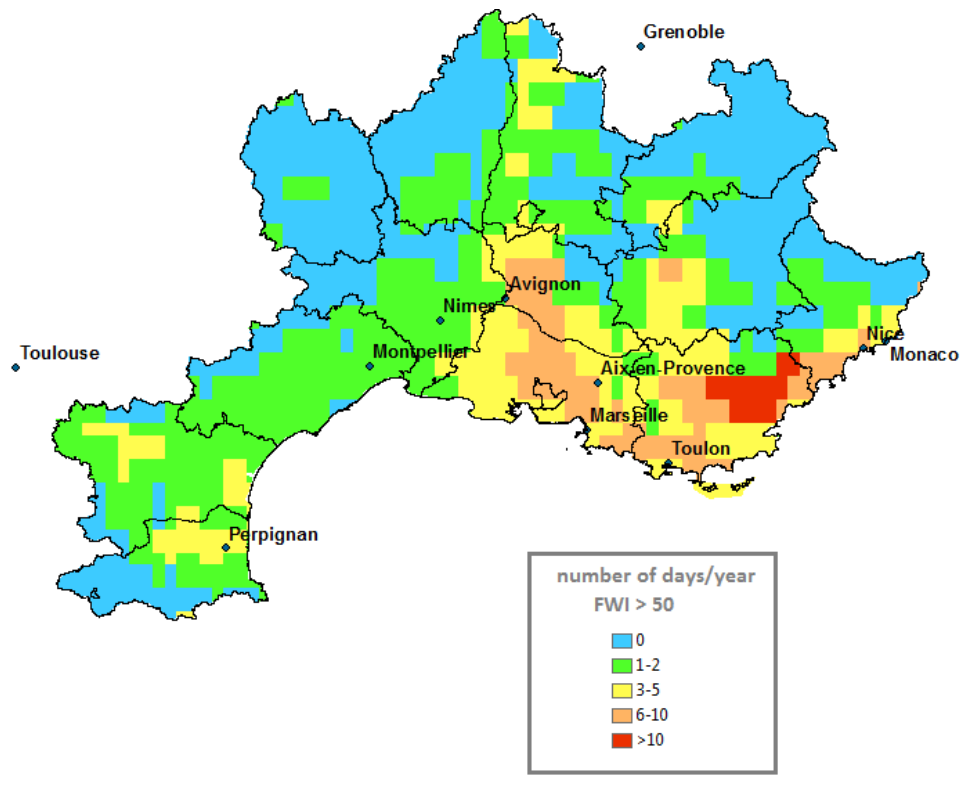


Figure 14 Climatic model MPI / RCP85/number of days/year FWI>50: period: 2006-2015

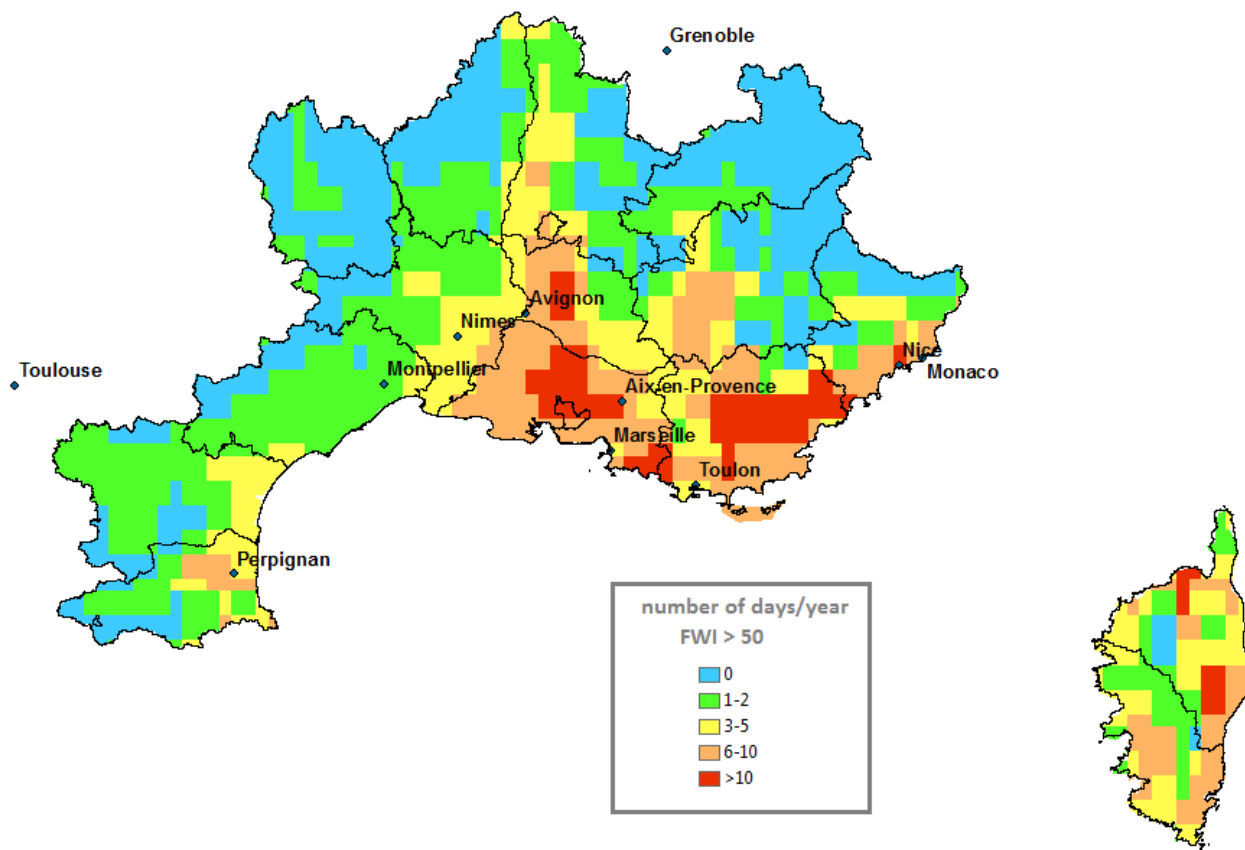


Figure 15 Climatic model MPI / RCP85/number of days/year FWI>50: period: 2036-2045

By observing figures 14 and 15, it is obvious that the fire risk is increasing for the majority of the PACA area.

The presentation of such results interested a lot the operators all along the meetings we had with them, and so, additional maps and parameters were added, as the following;

- The initial Spread Index: it is a very pertinent parameter representing the numeric rating of the expected rate of fire spread. It combines the effects of wind and the FPMC on rate of spread without the influence of variable quantities of fuel.

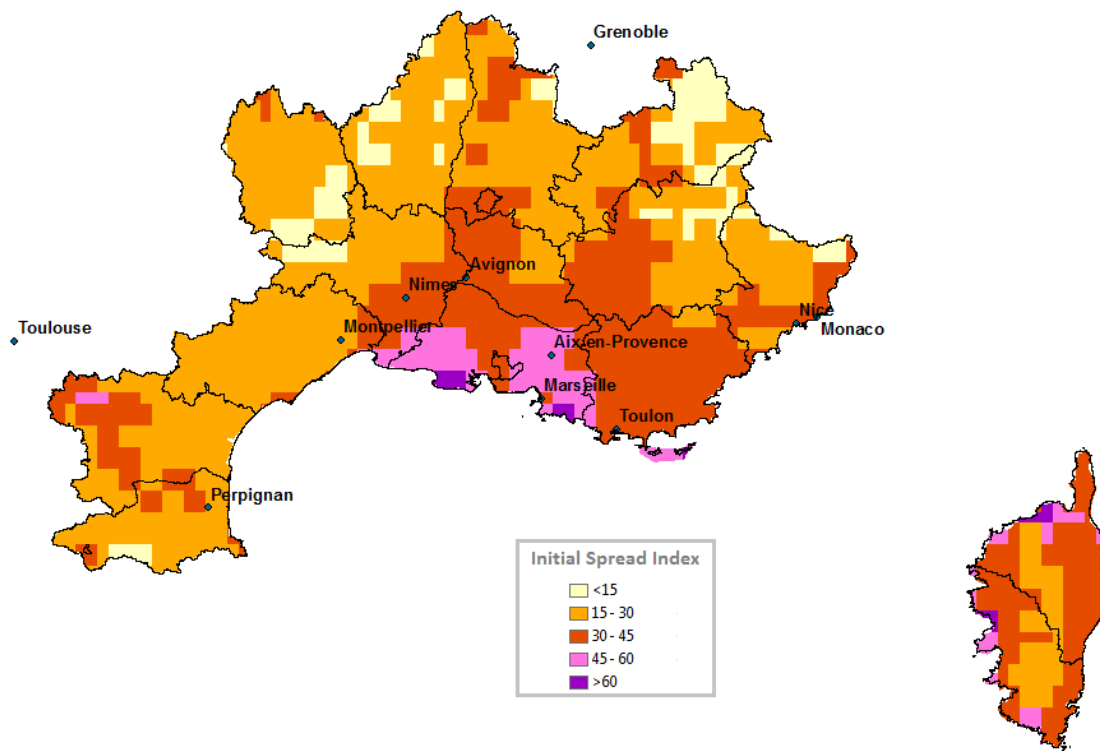


Figure 16 ISI : 2006-2015

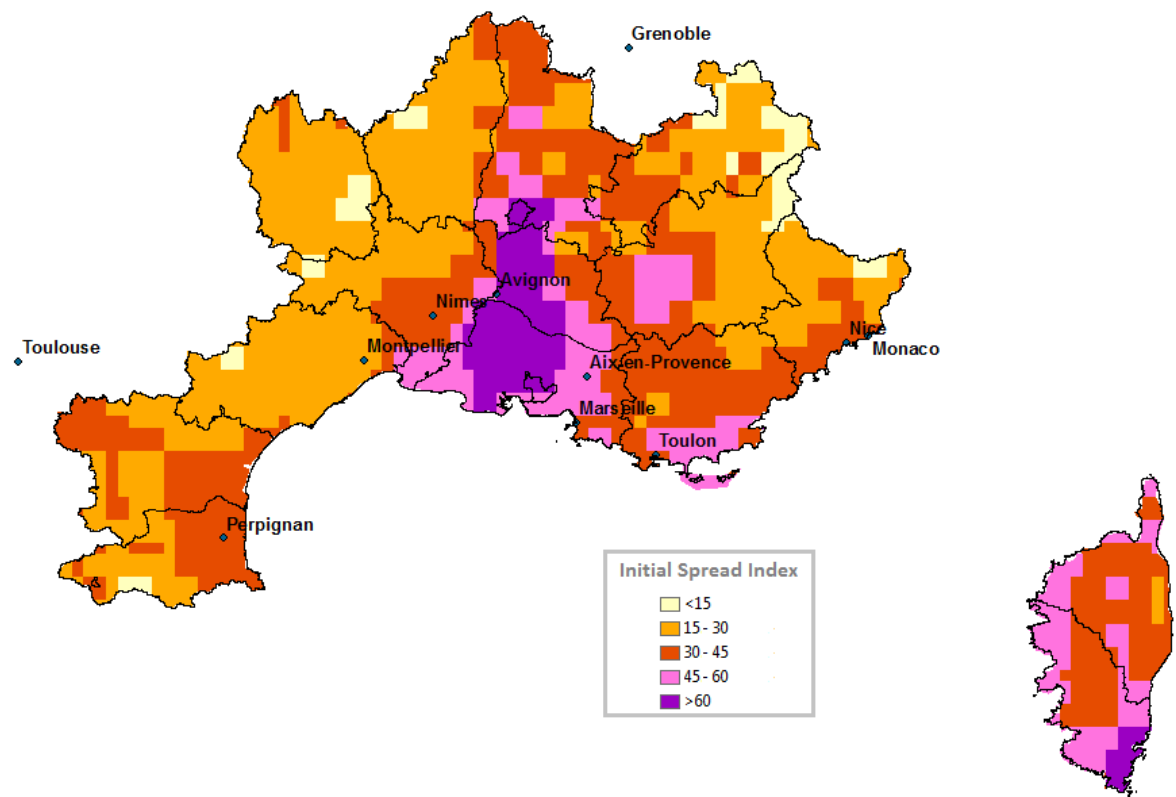


Figure 17 ISI : 2026-2035



The analysis of this parameter show that it will increase in the next decades. This means that the Climatic conditions will be more conducive to fire spread. Then, additional prevention actions, mainly on fuels have to be done in order to reduce the fire propagation index.

- The Fire simulation model, FIRETACTIC, was used to simulate fire contour evolution on a given scenario. For the scenario, the fire duration was of 4 hours.
- The fire rate of spread (ROS°) and the fireline intensity (FLIN) were derived from this Fire Simulation tool allowing the damages evaluation on the assets networks though the following damages functions:

To define risk classes, the following values, adapted to the concerned Mediterranean area were applied:

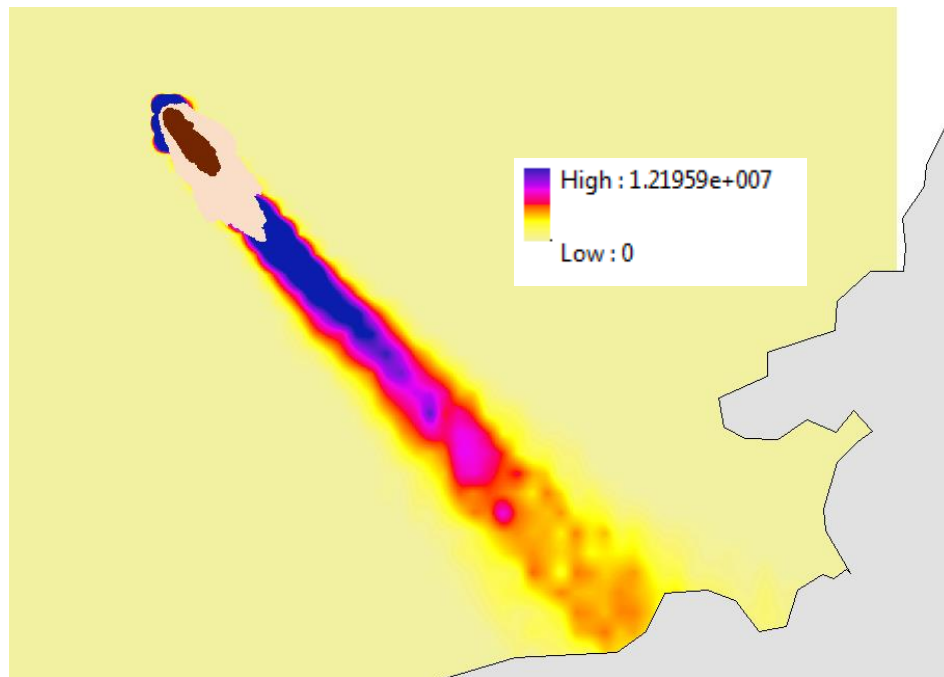
Parameter	units	Very Low	Low	Medium	High	Very High	Exceptional
FWI		<30	30-50	50-60	60-80	80-100	>100
FFCM		<84	84-89	90-93	94-94	>95	
DC		<80	80-200	200-300	300-700	700-1000	>1000
ROS	m/min	<3	3-8.5	8.5-20	20-50	>50	
FLIN	kW/m	<750	750-3500	3500-10000	10000-30000	>30000	

Fire Emission Production Simulator (FEPS) is a user-friendly computer program designed for scientists and resource managers with some working knowledge of Microsoft Windows applications. The software manages data concerning consumption, emissions and heat release characteristics of prescribed burns and wildland fires. For our specific scenario, the results of the model are linked to the following visibility classes:

No visibility	Medium visibility	Good visibility
$[PM_{\text{moyen}}] > 30 \text{ mg/m}^3$	$10 < [PM_{\text{moyen}}] < 30 \text{ mg/m}^3$	$[PM_{\text{moyen}}] < 10 \text{ mg/m}^3$
Roads/highway should be closed	Roads/highway should be closed	No closure of roads

Those results are used in the CIRP to close the road or highway of the impacted area.

The **Hybrid Single Particle Lagrangian Integrated Trajectory Model (HYSPLIT)** is a computer model that is used to compute air parcel trajectories and dispersion or deposition of atmospheric pollutants. Emissions/smoke modeling was based on wildfire simulation and fuel data for the French area of interest, which were the inputs to FEPS software. Application of HYSPLIT dispersion software for estimating smoke concentrations for three time steps.



Fire total simulation – 2/4 hours
& smoke total simulation ($\mu\text{gr}/\text{m}^3$) – 8 hours

- **Impact and damages**

The CIRP tool allows the evaluation of the direct impacts and damages on the various defined assets. The obtained results can be used by the critical infrastructure operators in order to evaluate:

- ✓ from one part which assets will be impacted, if they will be out of use during the duration of the event or completely destroyed
- ✓ from another part what should be the consequences on the other related networks

In our case, it is interesting to simulate several fire ignition points in order to analyze which assets should be regularly impacted and what should be the consequences on the various networks.

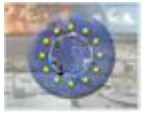
A first version of impact and damage was proposed for CS1 related to ROS and FLI according to the following rules :

- If $\text{ROS} > 800 \text{ m/h}$ or $\text{FLI} > 1700 \text{ kW/m}$ and burned area $> 50 \text{ ha}$, then wood electric poles start to burn and the ones in metal start to be damaged
- If $\text{ROS} > 1800 \text{ m/h}$ or $\text{FLI} > 70000 \text{ kW/m}$ and burned area $> 500 \text{ ha}$, then wood electric poles are all burned and the ones in metal are all damaged

The other proposed modules are the following:

- **Client not served with electricity:**

The number of clients connected to each electricity station and the state of each electricity station (damage yes/no?) Electric substations cut from electricity supply analysis: This analysis takes power lines,



electricity stations and fire contour datasets a user input. The power line data sets needs to have topological information, i.e. the ids of the electricity stations that are connected by this power line (including electricity flow direction indicated by source and target id). Power lines can be both types, aboveground/aerial or buried. It is analyzed, if an electricity station is connected to the electricity network by an upstream power line that is affected by a fire incident. If this is the case, the capacity of this power station is reduced by the amount of upstream not functional lines divided by the sum of all powerlines connecting this substation from upstream.

- **Highway Operator Loss of Revenue as cascading effect of electricity blackout:**

it analyses the loss of revenue (unpaid tolls) for highway operator due to highway shutdown as a result of electrical substation equipment damage. For this purpose, unpaid tolls due to damaged highway as a result of an electrical substation equipment damage are computed. Electrical substation equipment state is retrieved from highwaysTopology dataset. The number of vehicles that use highway segment per day retrieved from highwaysTopology dataset. *The duration of highway shutdown, loss of revenue per vehicle per hour have to be entered by the user. The current state of highway segment is defined by analysis of nearest substation. If the nearest substation is damaged then whole highway segment is damaged too. The analysis calculates the losses due to highway not working time by multiplying the number of vehicles by highway shutdown time and costs of revenue per vehicle.*

- **Highway Operator Loss of Revenue due to Fire Incident:** Scenario analyses the losses of revenue (unpaid tolls) for highway operator due to highway shutdown as a result of fire incident. For this purpose unpaid tolls due to damaged highway are computed. The number of vehicles that use highway segment per day from highwaysTopology dataset retrieved. The duration of highway shutdown and loss of revenue per vehicle per hour have to be entered by the user. The analysis calculates the losses due to highway not working time by multiplying the number of vehicles by highway shutdown time and losses of revenue due to fire incident

- **Estimated Number and Replacement Cost of wooden pylons Analysis:**

This analysis calculates the replacement costs of wooden pylons that have been burned during a fire incident. For this purpose, it is assumed that the exact location of each individual wooden pylon is known. In the analysis it is tested, if a given fire contour intersects with each individual pylon. If there is an intersection, it is assumed the pylon needs complete replacement. All other pylons do not have associated replacement costs. The replacement costs per pylon have to be entered as a user Input.

- **Transmission Tower Fire Physical Damage**

Determines if steel transmission pylons are physically damaged due to fire based on the following steps: get fireline intensity per computational cell, estimate temperature, find strength of structure, select exposure, determine fire duration, and finally find damage value from fragility curve.

3.4 Adaptation options

The adaptation framework aims to propose a decision support to identify (i) and prioritize (ii) options able to enhance the resilience, according to a scenario.

The final version of this framework, developed under the Task 4.4, wasn't yet available for this case study. However, the available material (adaptation option template and guidelines from the D4.6 first version) made it possible to conduct this analysis. An evaluation of impact of adaptation options on the resilience was conducted using the RAT, to visualize the improvement of infrastructures resilience.

3.4.1 Identify relevant adaptation options to improve the resilience

The operators were firstly invited to identify the action levers to improve the resilience, using the resilience assessment results and following the reverse logic of the Resilience Assessment Tool (RAT):

- (i) Identification of the lower resilience capacities using the overall resilience graphic;

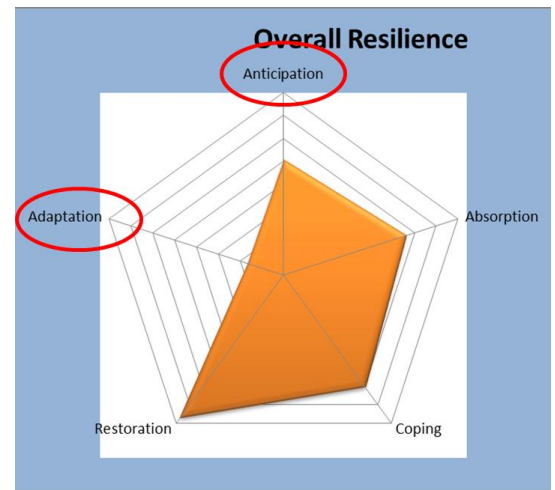
Example: adaptation capacity is the lowest capacity.

- (ii) For each low resilience capacity, identification of the lower indicators and categories;

Example: the operator doesn't have an adaptation plan to climate change impacts.

- (iii) For each low category, identification of potential action levers to improve the resilience.

Example: make and implement an adaptation plan is possible or not for the operator.



Each action selected needs to be specified in the perspective of its implementation. The EU-CIRCLE adaptation framework provides a template to help describing the identified options.

During the final workshop, the operators were invited to complete this template according to the levers of action they had identified.

Adaptation option table contents		[Inputs from]
Name of the action		[Adaptation module / end users]
Climate Hazard considered		[Risk assessment module - Climate data]
CI asset considered		[Risk assessment module - Asset builder]
Description of the action	<i>Objectives</i>	<i>[Adaptation module / end users]</i>
	<i>Mean</i>	<i>[Adaptation module / end users]</i>
	<i>Picture</i>	<i>[Adaptation module / end users]</i>
	<i>Cost</i>	<i>[Adaptation module / end users]</i>
CI properties changed by the action		[Risk assessment module - Asset builder]

Figure 14: adaptation option collection table (first version available used for the case study)

3.4.2 Prioritize the adaptation options identified

This part of the EU-CIRCLE adaptation framework was not yet totally developed for this case study. However, it was possible during the case study to propose two actions:

- (i) **Training:** each operator was invited to change his inputs in the end-user questionnaire of the Resilience Assessment Tool (RAT), according to the selected adaptation options, to visualize the consequences in terms of resilience capacity.

This operation aims to help operators to prioritize various options according to their impact in terms of resilience capacity.

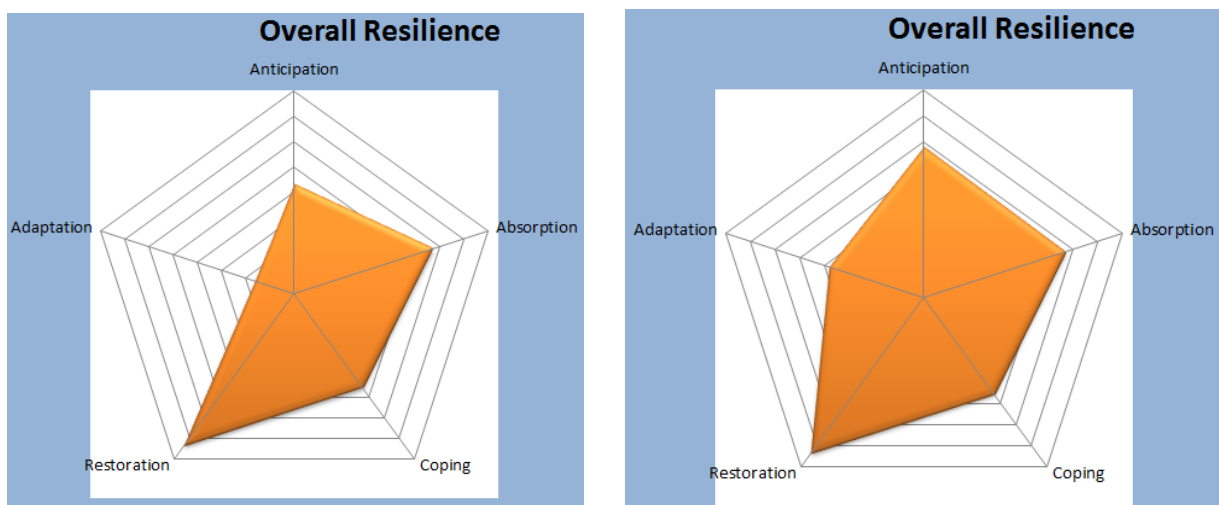


Figure 15: visualization of the consequences of adaptation options on the overall resilience graphic (illustration)

(ii) **Presentation** of the expected approach to select cost-effective adaptation options: even if it was not yet available to be test during the case study, the theoretical method was presented to the operators during the final workshop.

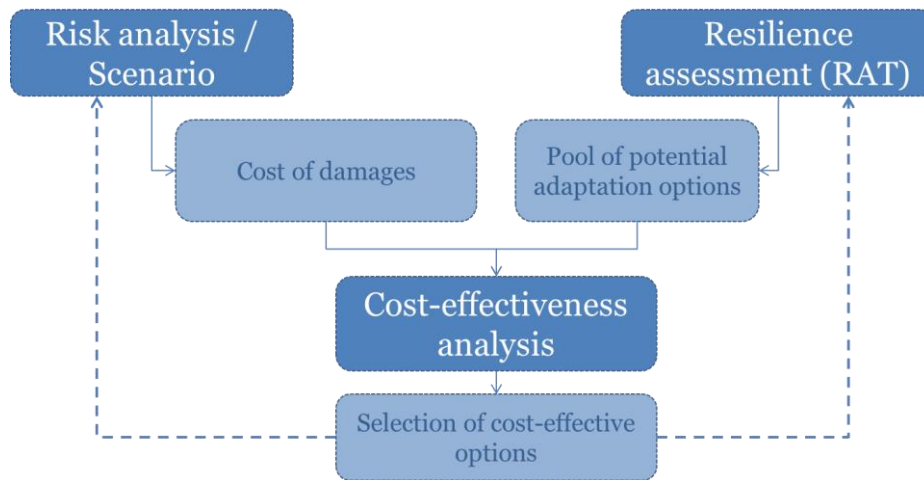


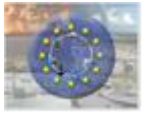
Figure 16: expected approach to select cost-effective adaptation options

4 Global lessons learned and recommendations

4.1 From the operators

The table below presents a synthesis of the recommendations made by the operators during the case study, classified by EU-CIRCLE analysis. The detailed questionnaires per operator are available in the Conduction report of the case study [D6.2].

Recommendations from the operators	
EU-CIRCLE analysis	Recommendations
Global recommendations	<p>Visualize the concrete hazards impacts in 2040 on the infrastructures and its consequences could be very useful to convince decisions makers to invest, prioritizing resilience capacities and adaptation options.</p>
Resilience assessment	<p>The end-user questionnaire is subject to interpretation, especially regarding min/max/average values. Providing guidelines (and examples) would be beneficial to help the end-user completing this questionnaire.</p> <p>Visualizing where capacity of resilience is high and where it is lower appears to be of high value because:</p> <ul style="list-style-type: none"> • It forces to question some of these capacities (that are not questioned today). • It is a powerful tool to grow awareness among decision makers on climate change risks on the infrastructure <p>RAT also appears to be an interesting tool of to compare the resilience capacity between similar infrastructures or networks in Europe.</p> <p>Finally, the resilience assessment results (from the RAT) may have an interest for the top management of CI since it could be helpful to take into account for future investments on the infrastructures.</p> <p>RAT is not considered to be a tool for the daily management.</p>
Climate analysis	<p>The operators involved in this case study are not familiar with climate change issues. The climate analysis presented during the case study will allow them to be much more aware on this topic and to help them in their future planning development analysis.</p>
Risk analysis	<p>The various Fire Weather indexes are relevant and could be used to refine fire prevention plans for the future decades The CIRP tool can be used to perform additional analysis by changing threshold parameters .</p> <p>This tool should be presented to the public authorities that are in charge of territorial planning. They have to be aware about the climate change impacts not only on critical infrastructure but on the global territory.</p> <p>The fire emission and smoke analysis will mainly help for the roads visibility and decision to cut a road. It could be used to understand some failure obtained on electric lines.</p> <p>The damages part of the tool can help to start a thinking on future</p>



investment.

Adaptation options

[Any explicit recommendations]

4.2 From CEREN and Artelia

The proposed climate analysis showed the numerous possibilities of working with the CIRP tool. Return period and extreme values should be more analysed in order to perform a deeper analysis with the climate change scenario results.

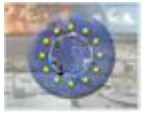
The Fire Indexes analysis is relevant to evaluate how fire risk and heat wave will evolve in the next decades. Nevertheless, this part of the tool will not be used by the critical operators to evaluate climate change in their future prevention plans, as it is not their mission. Despite this fact, they are very interested in having results of those Climate Change analysis. It is one of the mission that CEREN and DEMOKRITOS will perform now, with the objective of presenting to the operators the results of the climate analysis at the end of the project.

Concerning the damages and impacts proposed by the CIRP tool, the interest of having a global view of what could happen to the critical network in case of more severe fires is a real added value. No tool is currently available, limiting so the awareness of the decision makers and authorities concerning this issue.

As for every innovation and new tools, as proposed in the Eu-CIRCLE project, it is important in a first step to present to the potential future users what kind of results can be obtained and in a second time to support them in integrating the use of such a tool in their current activities.

It is obvious that the combined results of the various tools proposed in EU-CIRCLE will help managers to refine their various prevention planning and guide them for taking decisions about future investments.

In addition, the Climate Change part of the CIRP could be used by territorial managers or private companies involved in the elaboration of the prevention plans such as PPRIF (Forest Fire Risk Prevention Plan).



5 References

5.1 Bibliography

- [1] A. Camia, T. Durrant, J. San Miguel. *The European Fire Database - Technical specifications and data submission*. JRC Science and policy Reports, 2014.
- [2] D. Grandi. *Données Incendie* [online]. Università di Corsica Pasquale Paoli, 2012, [viewed on 16 February 2017]. Available on : http://anridea.univ-corse.fr/Donnees-Incendie_r8.html.
- [3] D. Tilsner, C. Figueiredo, H. Silva, B. Chartier, J. San Miguel, A. Camia, M. Millot. Metadata Model for the European Forest Information and Communication Platform, *International Journal of Spatial Data Infrastructures Research*, Vol. 2, 91-110, 2007.
- [4] R. Gazzard. *United Kingdom Vegetation Fire Standards, Data Fields and Terminology for Wildfire Incidents and Prescribed Burning Operations within Great Britain and Northern Ireland*. UK Forestry Commission, August 2009.
- [5] J. San-Miguel-Ayaz, E. Schulte, G. Schmuck, A. Camia. The European Forest Fire Information System in the context of environmental policies of the European Union. *Forest Policy and Economics* 29, 19–25, 2013.

5.2 Websites

<http://www.promethee.com/>

<http://forest.jrc.ec.europa.eu/effis/>

http://wfdss.usgs.gov/wfdss/WFDSS_Home.shtml

ⁱ INSEE