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A case study for Tenerife

Yeray Hernández-González, Ângela Guimarães-Pereira, Sergio Rodríguez, Emilio Cuevas and Paulo Barbosa

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Contact information
Name: Yeray Hernández-González
Address: Via Fermi, 2749, 21027 Ispra (VA) – Italy, Building 100 – Office 1107
Email: yeray.hernandez@jrc.ec.europa.eu
Tel.: +39 0332 78 3821

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Authors

Hernández-González, Yeray

Guimarães-Pereira, Ângela

Rodríguez, Sergio

Cuevas, Emilio

Barbosa, Paulo

Abstract

This technical report describes a case study on policy for adaptation to climate change delivered to DG-CLIMA. It is aimed at exploring climate change adaptation scenarios as well as concrete actions to increase climatic resilience in a small European island: Tenerife, Canary Islands (Spain), the largest and most populated of the seven islands of the Canaries. The effects of climatic and non-climatic hazards on local population health and ecosystems are reviewed, such as heatwaves, air pollution and the atmospheric dust which comes from the Saharan dessert. The potential combination or overlapping effects of these hazards are also explored.

According to the literature reviewed, heatwaves, air pollution, and Saharan dust events have been producing negative effects on the population, in terms of both morbidity and mortality, as well as the environment, such as forest fires related impacts. In terms of health impacts, elderly and people with chronic diseases are those more vulnerable to the previous hazards. As a consequence of both population ageing and the expected increasing extreme weather events, vulnerability is believed to worsen.

There are currently a certain number of policies at both the Canary Islands scale and at Tenerife scale that, either directly or indirectly, might deal with the multiple hazards analysed here. However, most of these policies have neither been specifically developed to increase the resilience against heatwaves, Saharan dust events, and air pollution, nor to deal with their potential interactions. Therefore, their possible capability need to be explored along with other potential adaptation options.

In order to do so, a participatory integrated assessment is proposed based on three steps: (1) a first one intended to define the issue under analysis and frame the *problematique* of adaptation to climate change in Tenerife by means of in-depth interviews and a questionnaire; (2) a second step envisioned to explore scenarios to increase the island resilience as well as concrete actions to reduce the vulnerability to heatwaves, Saharan dust intrusion, and air pollution, by means of focus group sessions; and (3) a last step projected to build the scenarios for resilience (this third phase will be carried out in a later stage). For this purpose, different participatory techniques have been applied, such as questionnaires, in-depth interviews and focus group sessions, involving local key stakeholders as well as citizens and lay people.

One of the findings of the analysis is that there is a lack of institutions in charge of climate change policy issues. According to most of the participants, the Islands need an institutional structure in charge of mainstreaming climate change policy into private and public institutions. A second finding indicates that an integrated climate change risk management plan is also needed as well as the investment in high-resolution regional climatic models.

The following part of this study will be devoted to build scenarios for Tenerife. As it emerged from the present study, local citizens are not only concerned about adaptation to climate change, but also about how to be more resilient against external shocks, including extreme weather events as a consequence of climate change. Thus, those scenarios, still to be built, will propose paths that Tenerife may walk through from current times to 2040 in order to increase its resilience. These scenarios would concentrate on energy, agriculture, and food dependency, as well as other driving forces that might affect Tenerife's resilience.

1 Introduction

Extreme weather events ([1]) have been increasing globally as a consequence of climate change, including warm extreme temperatures (IPCC, 2014b). Both, warm days and nights have increased globally, and heatwaves ([2]) have become more frequent, especially in Europe (EEA, 2012a, 2016; Kovats et al., 2014). Heatwaves are expected to occur more and last longer (IPCC, 2014b), whilst Southern Europe is expected to be the most affected area in terms of hot weather, experiencing the highest heatwave exposure (Kovats et al., 2014).

Impacts related to heatwaves might expose ecosystems and human health to significant vulnerability (IPCC, 2014b). European inhabitants suffer heat-related mortality, especially older people and those with chronic diseases (Kovats et al., 2014). The hottest summer in Europe in the last 500 years was observed in 2003, leading to high death rates (EEA, 2014) that caused 70,000 deaths in 12 European countries (EEA, 2015b). By 2050, heatwaves are expected to produce 120,000 additional deaths annually in the European Union, especially among older people (EEA, 2015b, 2016). Morbidity is also co-related to warm spells. In fact, it is known that skin eruptions, fatigue, cramps, syncope, heat exhaustion, and heatstroke might occur as a consequence of heat exposure (WHO, 2004).

Heatwaves are not only impacting on human health, but also on other species and ecosystems, as well as critical infrastructure, such as hospitals, transport and energy infrastructure, as a consequence of material overheating (Kovats et al., 2014; see alto Table 1). For instance, the heatwave of 2003 produced damages to road and rail transport systems, interrupted energy supply, and increased waterway transport prices as a consequence of low water levels (Kovats et al., 2014).

Table 1. How climate impacts affect urban living, working and moving.

	LIVING	WORKING	MOVING
HEAT	- Decreased comfort - Health risks - Increased energy use for cooling, decreased for heating	- Reduced labour productivity - Increased energy use for cooling, decreased for heating	- Discomfort on public transport - Rail buckling - Increased energy use for cooling, decreased for heating
WILD FIRES	- Health and safety risks - Damage to houses	- Damage to economic assets	- Transport route blockage

Source: EEA, 2016.

Since these impacts threaten the environment, societies, and economies, a certain number of adaptation policies have been carried out across Europe. Thus, France implemented in 2011 an adaptation policy in this direction as a consequence of the heatwave produced in 2003 (EEA, 2014). It consisted of preventing negative health effects through the provision of information to the general public when occurring heatwaves. Other local places in Europe have also developed heatwave stress prevention plans, such as the ones in Emilia-Romagna and Milan (Italy),

([1]) The IPCC define extreme weather events as "(…) an event that is rare at a particular place and time of year" (IPCC, 2014b, p. 123; IPCC, 2014a).

([2]) Defined as *"(…) periods of more than 5 consecutive days with daily maximum temperature exceeding the mean maximum temperature of the May to September season of the control period (1971–2000) by at least 5°C"* (Kovats et al., 2014, p. 1277).

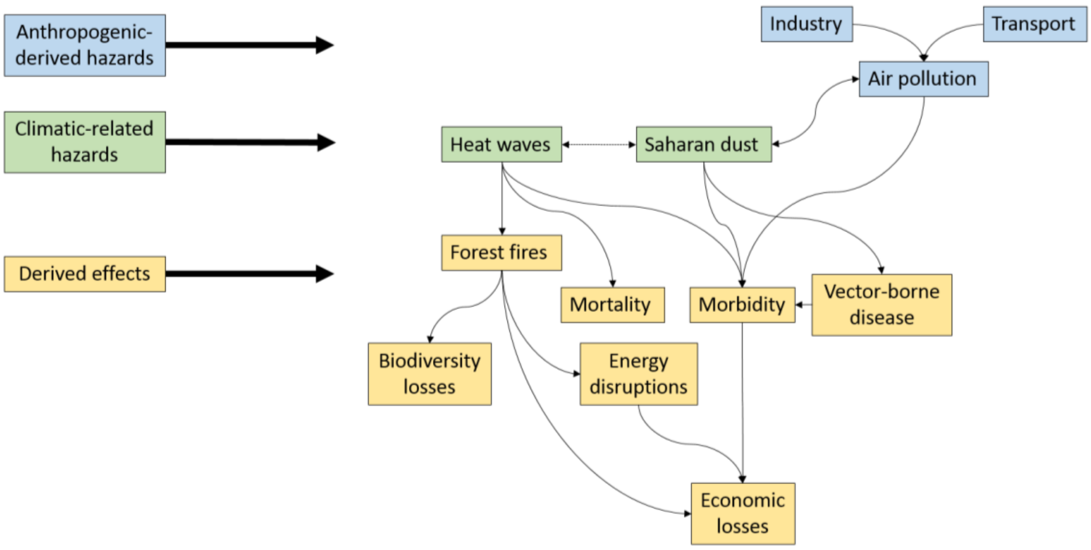
Botkyrka (Sweden), Geneva (Switzerland), Budapest (Hungary), and Stuttgart (Germany) (EEA, 2013a).

Additionally, heatwaves can be a contributing factor of air pollution. Thus, heatwaves usually appear together with tropospheric ozone (O_3), influenced by precursor air pollutants (nitrogen oxides, carbon monoxide, and hydrocarbons) along with meteorological determinants (EEA, 2015a). Therefore, high O_3 concentration levels are usually observed during major heatwaves in Europe (EEA, 2015a, 2015b; Kovats et al., 2014). These concentrations have caused not only morbidity in terms of cardiovascular and respiratory diseases (EEA, 2015b), but also about 20,000 premature deaths per year in Europe (EEA, 2012a). Furthermore, an increasing concentration of O_3 levels has been projected by means of future climate change scenarios (EEA, 2012a) ([3]).

Since heatwaves and air pollution are usually co-related, adaptation and mitigation policies can reinforce each other, bringing substantial co-benefits to society (EEA, 2016; IPCC, 2014b). For example, Belgium has developed a specific plan for heatwaves and O_3 peaks to deal with its increasing frequent combination (EEA, 2013a). Thus, the reduction of O_3 precursor emissions became an adaptation strategy as well as a mitigation one.

The present study will analyse the effects of climatic and non-climatic hazards (heatwaves, air pollution, and atmospheric dust), as well as their potential combination (see Fig. 1) on a small European island: Tenerife, Canary Islands (Spain). This study is aimed at developing scenarios for resilience and concrete adaptation actions for Tenerife by means of key local stakeholders' engagement. The conclusions will be delivered to DG-CLIMA.

Figure 1. Underlying causes of multiple hazards in Tenerife



Source: own elaboration based on the participatory techniques applied.

Note: the discontinuity between heat waves and Saharan dust indicates that winter dust season (November – March) are not necessarily associated with high temperatures.

The following sections of this report are organised as follows: in section 2 the case study will be presented; the state-of-the-art regarding both climate change related impacts and existing policies will be provided. Section 3 is devoted to present the methodology to be applied in this case study. Section 4 will present the results of the analysis and these results will be discussed in section 5. Lastly, in section 6 the conclusions obtained in this study will be highlighted.

([3]) Particulates (PM_{10}) are also related to hot weather (EEA, 2012a).

2 Multiple climatic and anthropogenic hazards

In this section the specific characteristics of multiple hazards in Tenerife will be reviewed. As presented in the previous section, the present case study will focus on the potential combination of climatic and anthropogenic hazards (multiple hazards) that either in an isolated manner or altogether may increase population health and ecosystems' vulnerability.

Initially, these hazards will be presented separately in order to understand their specific causes and consequences. Later on, in a second stage, these hazards will be presented as multiple-hazard analysing possible interactions.

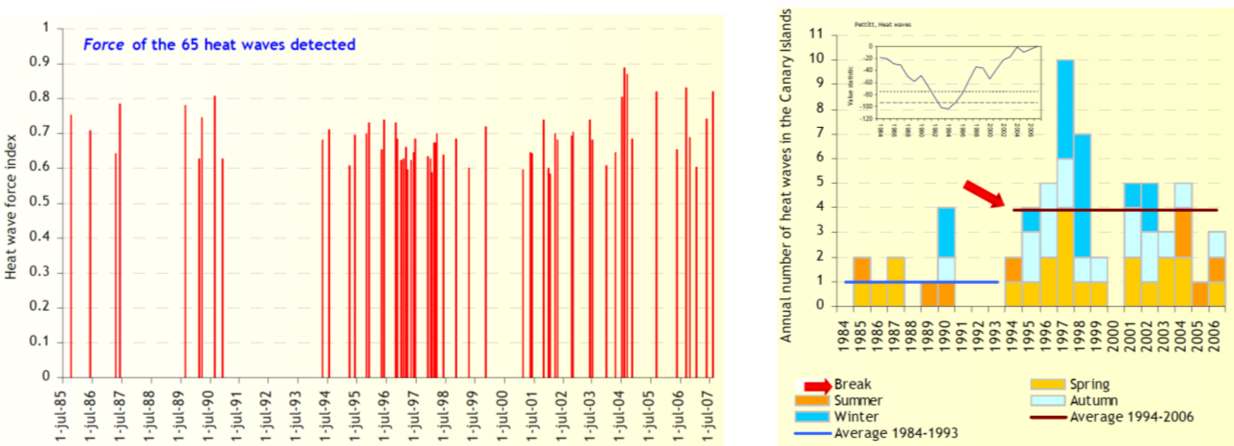
2.1 Heatwaves

Climate in the Canary Islands is mild, due to the influence of the template NNE trade winds and the cool waters of the subtropical North Atlantic. These conditions prevent these Islands of the extreme weather conditions of the nearby Sahara, the largest and among the hottest desert in the world. Episodically, cool trade wind weakens and easterly Saharan air reaches the Canaries. These Saharan air masses may prompt high temperatures, drops in relative humidity, down to ~15% (Dorta, 1991) and the presence of suspended desert dust.

These heatwaves are mainly produced between spring and autumn (Dorta, 2007), usually reaching temperatures of 44-45 degrees (Dorta, 1991). However, the Island Council of Tenerife has considered heatwaves as those temperatures exceeding 30 degrees (Cabildo de Tenerife, 2016). Night heat events reach national maximums between 26-30 degrees (Dorta, 2007).

The most dangerous heatwaves took place on August 1990 and July 2004 (Dorta, 2007; see also Fig. 2), although other relevant heatwaves can also be seen in Table 2. According to Alonso-Pérez (2007), these episodes might have acquired more intensity and frequency in the Canary Islands since 1970. In fact, according to Fig. 2 (right graph), the average number of heatwaves has quadrupled since 1994. The left graph in Fig. 2 also indicates that among the 10 strongest heatwave's force indexes recorded over the whole period, 5 have been detected during 2004-2007. Other authors also mention that a general rise of temperatures is expected for the Canary Islands (Martín et al., 2012), intensified in upper parts of the islands (Expósito et al., 2015; Martín et al., 2012).

Figure 2. Heatwave frequency and intensity in the Canary Islands (1984-2007)



Source: Sanz et al., 2007.

Table 2. Main heatwaves in Tenerife (1950-2004).

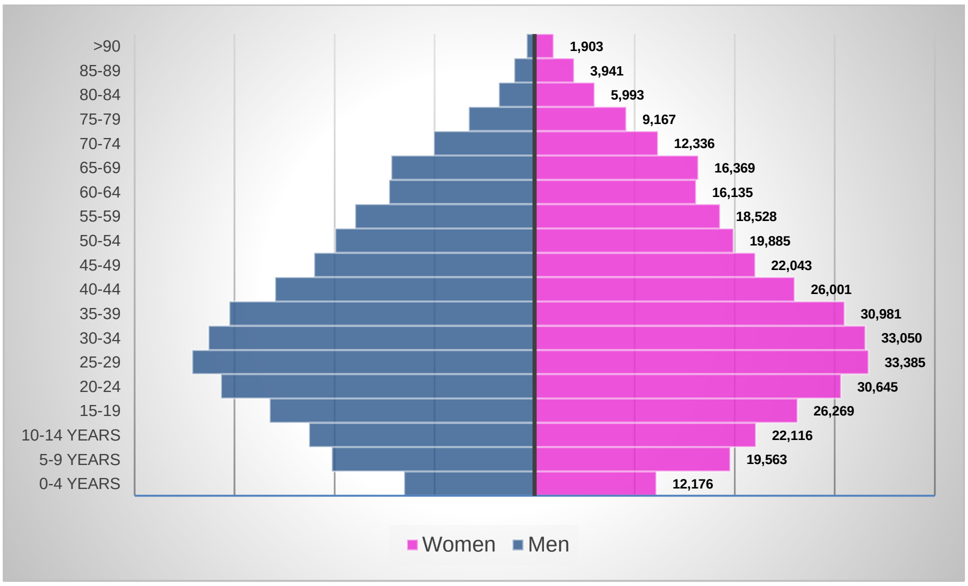
Episode	**Degrees**
Santa Cruz de Tenerife	
July 1940	40.4
August 1952	42.6
September 2006	39.3
Tenerife North Airport	
August	41.2
July	41.4
Tenerife Sur Airport	
September 1986	41.8
August 1988	44.3
July 2007	42.9

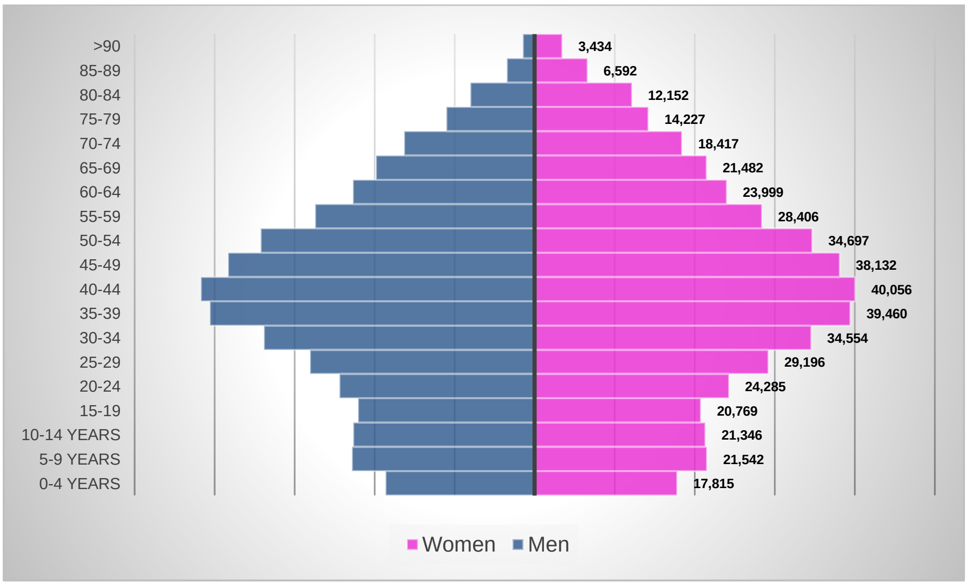
Source: AEMET, 2016.

According to the World Health Organization, the most relevant predisposing factors for heat-related illnesses are being elderly, having impaired cognition (such as dementia), pre-existing diseases, use of certain medications, low level of hydration, living alone, poor housing (such as living in a certain building type or on the top floor), the lack of air-conditioning at home or residential institutions (WHO, 2004). Thus, the last heatwaves registered in the Canary Islands have left 13 premature deaths, more than any other meteorological hazard (Dorta, 2007).

According to the Canary Islands Statistic Institute (ISTAC, 2016d), the number of elderly people in Tenerife were almost 128,000 in 2015, representing 14% of the population, whilst in 2000 they were about 80,000 (11%). An increasing number of elderly people is also expected in the future, if we attend to the population pyramids shown in Fig. 3. This will probably increase the number of vulnerable people, especially in a context of growing frequency of heatwaves and Saharan dust events in the Islands (Martínez, 2010; Sanz et al., 2007).

Figure 3. Population pyramids for Tenerife. Years 2000 (upper) and 2015 (lower)





Source: own elaboration based on ISTAC, 2016d.

In Table 3 additional information data on potential population vulnerability can also be seen. For example, the proportion of homes with air conditioning is low ([4]), whilst there is a relevant percentage of population living alone. Besides, the percentage of inefficient building is quite relevant as well, since more than 84% of homes are F-G energy class, i.e. the lowest in terms of isolation efficiency.

([4]) It should be noted that the availability and use of air-conditioning devises helps population to adapt to heatwave events. However, since they consume increasing quantities of energy, air-conditioning usage contribute with climate change. This is the typical measure that could be understood as maladaptation (Barnett and O'Neill, 2010).

Table 3. Vulnerability indicators for heatwaves. Data for Tenerife (year 2013).

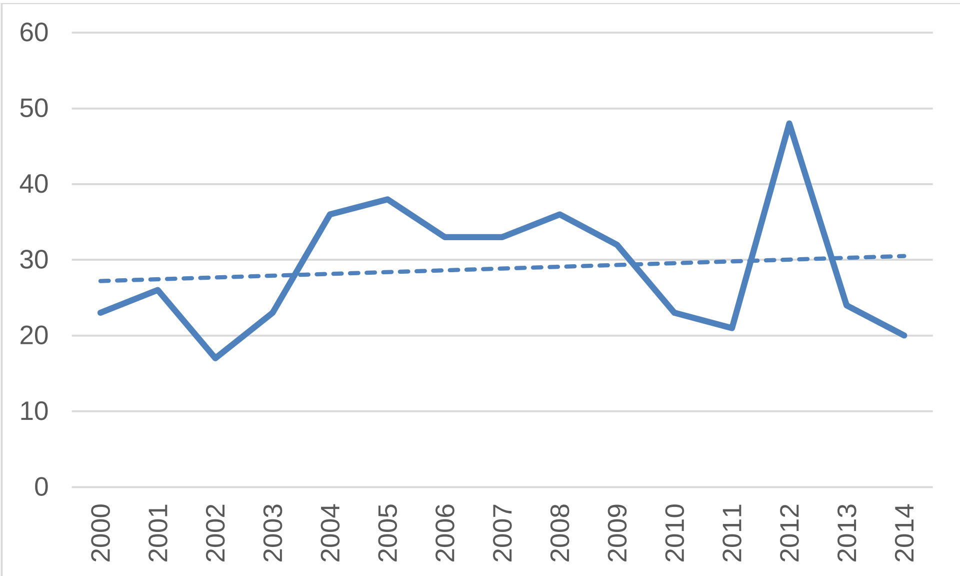
Homes with air conditioning	10,2%
Homes with uninsulated windows	11,6%
Homes with electricity problems	7,6%
People living alone	22,5%
People unable to move	9,2%
Energy efficient homes (class A) (1) Energy efficient homes (class B) (1) Energy efficient homes (class C) (1) Energy efficient homes (class D) (1) Energy efficient homes (class E) (1) Energy efficient homes (class F) (1) Energy efficient homes (class G) (1)	0.5% 1.4% 3.2% 3.0% 7.6% 7.7% 76.6%

(1) Refers to the Canary Islands.

Source: own elaboration based on IDEA, 2015 and ISTAC, 2016a.

Heatwaves might also be a contributing factor to forest fires, leading to power distribution network damages and, therefore, blackouts, affecting public transport (tram transport mainly) and public services (IPCC, 2014a). Other related impact concerns road accident risks as a consequence of increasing heat-stress conditions (Koetse and Rietveld, 2009). In Tenerife, the number of forest fires have been increasing in the last fourteen years (see Fig. 4).

Figure 4. Number of forest fires in Tenerife (period 2000-2014)



Source: own elaboration based on ISTAC, 2016c.

Among 20 and 40 forest fires usually occur in annual basis, except for the years 2002 (with 17 forest fires) and 2012 (with 48). In terms of hectare of forest burnt, on average 33 hectare have burnt per fire event, but years 2007 and 2012, where almost 17,000 and 7,000 hectare were burnt (ISTAC, 2016c). The forest fire occurred in 2007 has been considered one of the worse ever recorded in the Canary Islands (Huesca et al., 2008). This fire could not be early controlled because adverse environmental conditions (high temperatures, low humidity and moderate to strong wind) present during its inception.

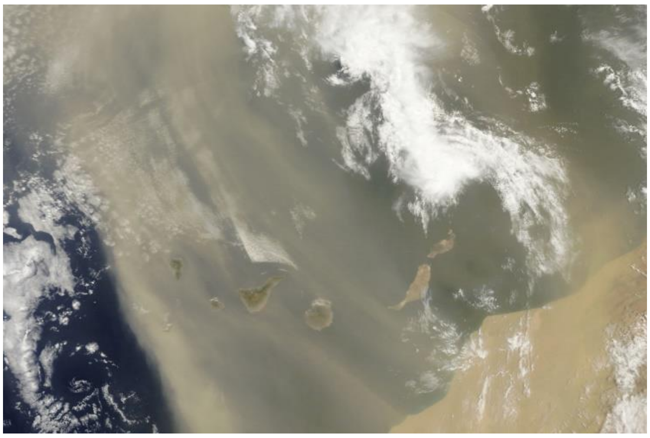
Thus, pine affected forests have been said to be related to negative effects on endemic bird communities characteristics in Tenerife (García-del-Rey et al., 2010), as well as to partial damage of aerial seed bank and/or the formation of unfavourable seedbed environments for growth and seedling development (Otto et al., 2009). Other studies indicate, however, that pine forest fires may have some positive effects on soil quality (Hernández et al., 2013).

2.2 Dust from the Sahara desert

There are two dust seasons in the Canary Islands, one in winter and other in summer. In the winter dust season (November – March) Saharan dust events are associated with the easterly winds prompted by the occurrence of high pressure expanding from the North Atlantic over Western Europe and North Africa (Alonso-Pérez et al., 2011a). These events may induce extremely high concentrations at ground level (up to 2,000 μg/m^3 have been recorded) and are not necessarily associated with high temperatures. Dust concentrations has increased by a factor 2 since 1980 due to an enhancement in dust export to the Canaries due to a strengthening and eastward shift of the Azores High (Alonso-Pérez et al., 2011b).

In the summer season (July and August) dust events are associated with the circulation of the dusty Saharan Air Layer (SAL) - i.e. the hot and dry airstream that expands from North Africa to the Americas - over the Canary Islands. The SAL results in hot, dry and dust air between 500 m.a.s.l. and 5 km.a.s.l. over the Canary Islands, whereas trade winds prevails below. A unique long term record of aerosol chemistry and dust at Izaña Observatory (Tenerife), started 3 decades ago, have shown that this summer dust export in the SAL has been modulated by large scale climate related processes by the so-called North African Dipole Intensity (NAFDI), i.e. the intensity of the North African high (over Northern Algeria) to the tropical monsoon (Rodríguez et al., 2015). Recent long-term analysis (1941-2013) of aerosol optical depth retrievals obtained at Izaña Observatory shows that there is an important multidecadal variability in summer dust export connected to NAFDI and North Atlantic ocean temperature long-term variability (García et al., 2016). The Canary Islands have historically received Saharan dust as a consequence of large scale meteorological processes that involve mid-latitude waves, the NAFDI and the Saharan Heat Low (Cuevas et al., 2016; Rodríguez et al., 2015). Thus, when this event takes place, the air of the Canaries become dusty and «naturally» polluted with particulate matter (PM_{10}). See Fig. 5. In addition to the dust events in these two seasons, other scattered and sporadic episodes may occur along the year.

Figure 5. Saharan dust events in the Canary Islands



Source: image of Saharan dust on the Canary Islands, captured by NASA.

Saharan dust events are therefore a common natural climatic condition that usually occur several times along a year (Dorta, 2007). This dust intrusion could also be understood as natural air pollution (see next section), since the air of the Canaries are impacted by mineral dust particles, surpassing 100 µg/m^3 and sometimes even 1,000 µg/m^3 (Alastuey et al., 2005; Alonso-Pérez et al., 2007; Dorta et al., 2005; Viana et al., 2002). One natural consequence of these events is that the average PM_{10} background level could be estimated at 14 µg/m^3 of total suspended particles (Alonso-Pérez, 2007; Alonso-Pérez et al., 2007).

In terms of socio-economic impacts, reduced visibility tend to affect both airports and their transport services (Dorta, 2007; see also Table 4). However, the impacts on human health are one of the most relevant ones, since respiratory pathologies, anxiety disorders, and atypical thoracic pain usually affect local population (García et al., 2001). Other studies have reported allergic diseases leading to increased use of air liquid as a respiratory therapy (Belmonte et al., 2010). It has also been testified that Saharan dust events might be related to the introduction of microbial communities (González et al., 2013).

Table 4. Expected Saharan dust-related impacts in the Canary Islands.

Impacts on critical infrastructure	Airport service disruptions due to reduced visibility
Social impacts	Car accidents due to reduced visibility
Health-related impacts	Negative health effects on people with chronic diseases
Environmental-related impacts	Forest fires

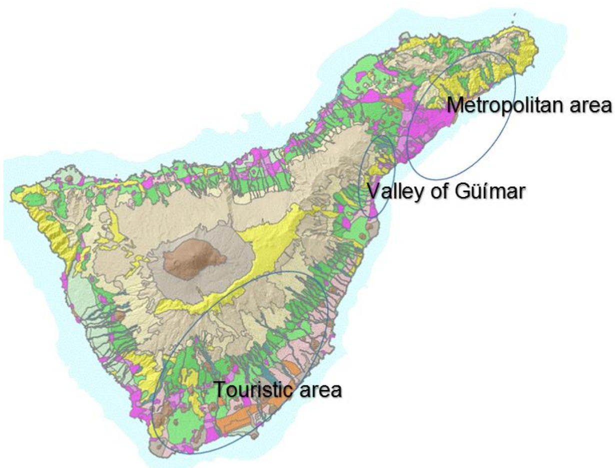
Source: Gobierno de Canarias, 2006.

Since this natural event is related to air pollution, and might therefore be considered as one relevant cause of poor air quality (Baldasano et al., 2014), Saharan dust will be indirectly treated in the next section too.

2.3 Air pollution

Tenerife has three main areas affected by air pollution (see Fig. 6). The first one is the metropolitan area, which is formed by two Municipalities, Santa Cruz de Tenerife and San Cristóbal de La Laguna. The second area is located southwest of the metropolitan area, and it is formed by the Municipality of Candelaria, Arafo, and Güímar (called Valley of Güímar). Lastly, the third area, which expand over three Municipalities (Arico, Arona, and Granadilla de Abona) is larger and is located south, the most important touristic area of Tenerife.

Figure 6. Areas affected by air pollution



Source: own elaboration based on Ecologistas en Acción, 2014 and SIMAC, 2008.

Air pollutant emissions in these three areas are associated with different sources (see Table 5): power plants (located in Valley of Güímar, in Granadilla de Abona and in COTESA within the refinery of Santa Cruz de Tenerife), oil refining (Santa Cruz de Tenerife), and vehicle exhaust (SIMAC, 2008). Vehicle exhaust emits carbon monoxide (CO), nitrogen oxides (NO_X), black carbon and ultrafine particles, whereas power plants, the oil refinery, onshore shipping (maritime transport) are associated with heavy oils burning and pollution due to sulphur dioxide (SO_2), heavy metals (including nickel and vanadium), organic compounds and ultrafine particles (González et al., 2011; González and Rodríguez, 2013; SIMAC, 2008).

Local and regional pollution transport is strongly modulated and influenced by the sharp orography of the island, being the Metropolitan area the most affected by air stagnation and subsequent specific strong pollution events (Milford et al., 2008).

The metropolitan area is affected by different pollutants, especially particulate matter (PM_{10} and $PM_{2.5}$) and sulphur dioxide (SO_2). Concentrations of these pollutants have also been above the limit value recommended by the World Health Organization in their Air Quality Guidelines ([5]) (Ecologistas en Acción, 2014). Thus, the number of days exceeding PM_{10} daily limits are between four and fourteen, meanwhile the average annual value is also surpassed; the number of days exceeding $PM_{2.5}$ daily limits are between four and nine days, whilst SO_2 daily value is exceeded four days a year. The concentrations of SO_2 have exceeded the European Air Quality Limit Value for the health protection, according to the European Environment Agency (EEA, 2013b), and this has resulted in the activation of the Air Quality Plan for the Government of the Canary Islands with legal implications for decreasing SO_2 emissions by a 29% (BOC, 2014). Scientific studies have also alerted on the high concentrations of heavy metals and industrial pollution under adverse meteorological conditions (Alastuey et al., 2005; Ares et al., 2011).

Table 5. Sources of air pollution in Tenerife.

Air pollutant	**Source**
PM_{10}	Energy production Refinery Maritime and road transport Saharan dust Ocean salt
$PM_{2.5}$	Refinery Maritime and road transport
SO_2	Refinery Energy production Maritime and road transport
O_3 ([1])	Refinery Energy production Road transport Long range transport processes

([1]) O_3 is a secondary air pollutant. This means that O_3 is formed by photochemical reactions between sunlight and nitrogen oxides (NO_X), as well as volatile organic compounds (VOCs).

Source: Guerra et al., 2004 and SIMAC, 2008.

([5]) These limits can be consulted in WHO (2006).

The Valley of Güímar is not only affected by the same pollutants as the metropolitan area, but also by O_3. The exceedances of this pollutant can be seen in Fig. 7. These pollutants are also exceeding the WHO recommendations (Ecologistas en Acción, 2014). Thus, the number of days exceeding PM_{10} daily limits are between nine and twelve; four exceedances for the $PM_{2.5}$ daily limits is also pointed out; forty-one exceedances for the eight-hour O_3 value have been detected; and between nine and forty-nine exceedances for the SO_2 daily value have also been reported.

Figure 7. 93.2 percentile of O_3 maximum daily 8-hours mean value in 2013

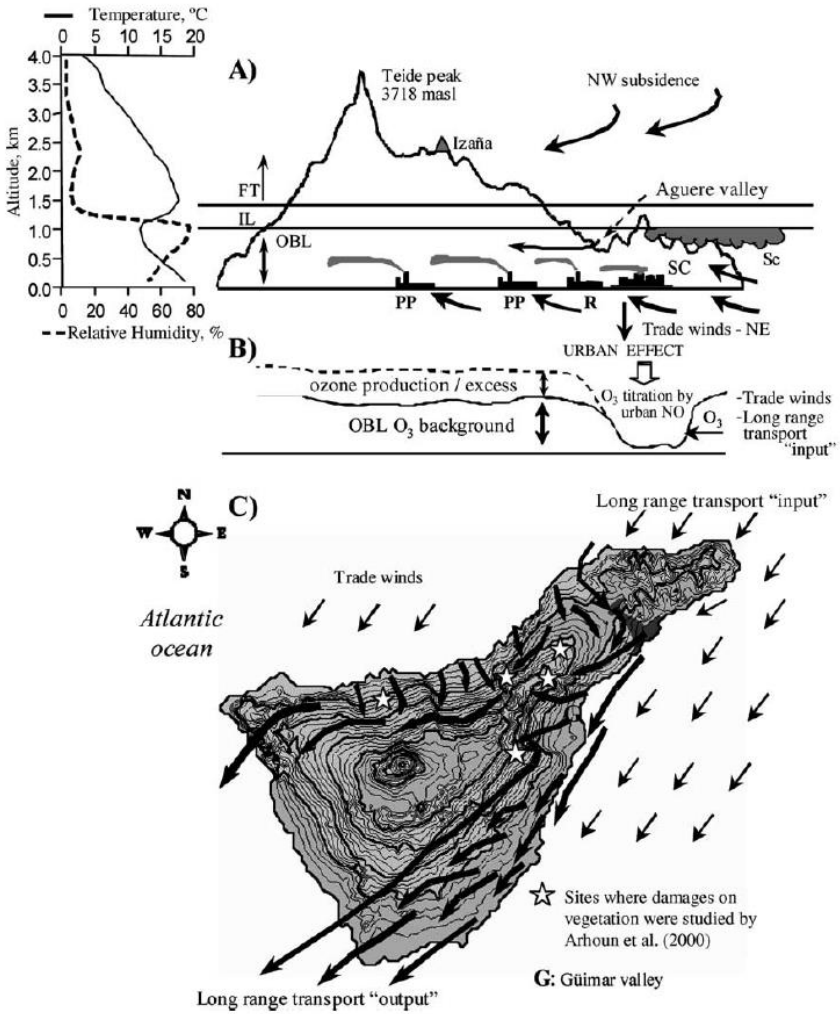
Source: EEA, 2015a.

Note: The map shows the 93.2 percentile of the O_3 maximum daily 8-hour mean, representing the 26th highest value in a complete series. It is related to the O_3 target value, allowing 25 exceedances over the 120-µg/m³ threshold. At sites marked with red and dark-red dots, the 26th highest daily O_3 concentration exceeded the 120-µg/m³ threshold, implying an exceedance of the target value threshold. Only stations with > 75% of valid data have been included in the map.

The Southern area share the same problem as the Valley of Güímar in terms of air pollutants (Ecologistas en Acción, 2014), except for O_3 concentrations, that are more relevant in this area (see Fig. 7 above). The number of days exceeding PM_{10} daily limits are between ten and eighteen, meanwhile the average annual value is also surpassed; between four and ten exceedances for the $PM_{2.5}$ daily limits are also detected, as well as the annual average value; thirty exceedances for the eight-hour O_3 value have been reported; and twenty-nine days for the SO_2 daily value as well.

Ozone is a secondary air pollutant that forms within the range of hours to days after the emissions of their gaseous precursors (volatile organic compounds, NO_X and CO). Because NNE inland winds prevails along the Eastern coast of the Island, the Valley of Güímar to the Southern area receives aged polluted air resulting in higher O_3 impacts compared to other parts of the Island. This is illustrated in the conceptual model (Fig. 8) of Guerra et al. (2004). In this conceptual model, background levels of O_3 are associated with long-range transport, whereas values above it are due to ozone formation within Tenerife (Guerra et al., 2004; Rodríguez and Guerra, 2001; Rodríguez et al., 2004).

Figure 8. Conceptual model for the air pollutant dispersion and long-range-transport in Tenerife



Source: Guerra et al, 2004.

Note: (A) Left: Vertical structure of the low troposphere, showing the limit of the oceanic boundary layer (OBL), inversion layer (IL), free troposphere (FT). Right: Vertical contour of Tenerife showing the southward dragging of pollutants and the stratocumulus cloud mantle (Sc) stagnant in the northern side. PP: oil-fired power plant, R: refinery; SC: Santa Cruz city. (B) Scheme of O_3 behaviour, sources and sinks. (C) Trade winds pattern (thin short lines) and pathways of the polluted air masses (long coarse lines) in the boundary layer of Tenerife.

There are evidences on impacts of air pollution in Tenerife. The *Hospital Universitario de Canarias* and the Izaña Atmospheric Research Centre found that exposure to ultrafine particles is associated with hospital admissions due to heart failure (Domínguez-Rodríguez et al., 2011), whereas black carbon has been associated with Acute Coronary Syndrome (Domínguez-Rodríguez et al., 2015, 2016). Other studies have also observed relationships between NO_2 and the ejection capacity of the heart (Domínguez-Rodríguez et al., 2013a) and between SO_2 and obstructive lesions and Acute Coronary Syndrome (Domínguez-Rodríguez et al., 2013b).

It has also been detected concentrations of potential pollutant particles in pine forests in Tenerife, possibly related to traffic emissions as well as sulphur transported from the industrial areas of Santa Cruz de Tenerife and Candelaria (Tausz et al., 2005). Meanwhile, it is also known that the exposure of vegetation to O_3 might imply injuries in Tenerife's vegetation (Guerra et al., 2004).

2.4 Multi-hazard events

The combination of the previous climatic and anthropogenic hazards might be produced as a consequence of the combination of (BOC, 2014; Rodríguez et al., 2008; SIMAC, 2008):

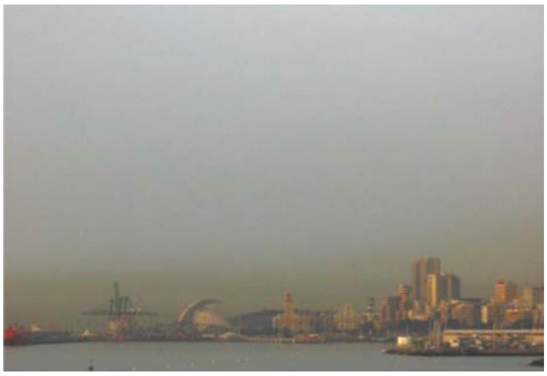
1. Emissions of air pollutants by different sources (see the previous section).
2. Thermal inversion layers.
3. Saharan dust events.
4. Local orography.
5. Local wind.

Summer dust events are associated with meteorological conditions that have several environmental implications. Aircraft measurements and satellite observations (Prospero and Carlson, 1972; Tsamalis et al., 2013) have shown that the dusty, hot and dry Saharan Air Layer typically expands between 1 and 5 km.a.s.l. over the ocean. Atmospheric soundings have shown that during intense events, the SAL occurs above 500 m.a.s.l. over Tenerife, shifting the typical inversion layer associated with the trade winds to lower altitudes and resulting in high temperatures in the forest of the Island that typically occurs between 600 and 1800 m.a.s.l. These high temperatures represented an increased risk of forest fires, whereas the shifting to low altitudes of the inversion layer is typically associated with severe pollution episodes of industrial origin in the metropolitan area, due to the emissions of the oil refinery and shipping in the harbour of Santa Cruz de Tenerife (Alastuey et al., 2005; CSIC-AEMET-UHU, 2010).

The most important sources of air pollutants in Tenerife are located along the Eastern coast of the Island (harbour and oil refinery in Santa Cruz de Tenerife, Caletillas and Granadilla power plants). The prevailing NNE trade winds coupled with the inland sea breeze blowing during daylight prompts the inlands transport of these pollutants. In Santa Cruz de Tenerife, the inland sea breeze blowing results in the inland transport of the SO_2 plumes from the refinery and from harbour, prompting fumigations of SO_2, sulphuric acid and ultrafine particles to the population of the city from 10 to 17 GMT (González and Rodríguez, 2013; Rodríguez et al., 2008). This situation worsens under summer SAL conditions due to the concentration of the air pollutants at low altitudes linked to the downward shifts of the inversion layer and to heterogeneous reactions between pollutants and Saharan dust (Alastuey et al., 2005; CSIC-AEMET-UHU, 2010). A similar scenario occurs in the Valley of Güímar, where the inland NNE winds drag the pollutants transported from the metropolitan area and emitted in Candelaria power plant to the interior of the Valley to the central ridge that crosses the Island (Fig. 9). In fact, traces of these air pollutants are transported upward across the forests to Izaña Observatory at 2,400 m.a.s.l., where they are detected during the upward upslope winds (García et al., 2014; Rodríguez et al., 2009). This transport of air pollutants within the Güímar Valley have implications on the residential areas (Fig. 6, coloured in pink).

When all these climatic factors appear together along with the emission of pollutants, the concentration of toxic air pollutants tend to exceed the recommended levels (see section 2.3). Thus, hot weather and air pollution (both natural and anthropogenic) stifle main island cities (see Fig. 9).

Figure 9. Multiple hazards in Santa Cruz de Tenerife



Note: the upper picture refers to hot weather, dust, and air pollution events acting simultaneously; the bottom picture only refers to an air pollution event (taken by Sergio Rodríguez).

The combination of these multiple hazards, their risk level and their derived effects can be seen in Table 6. Thus, the risk level of having heatwaves have been assessed as «high», meanwhile Saharan dust events as «moderate». Industrial environmental pollution is considered as «low», although the concentrations of air pollutants have been exceeding the World Health Organization recommendations (see section 2.3). Heatwaves might be related to Saharan dust, but also to different sort of fires, environmental pollution and infrastructure collapse. Saharan dust events are also connected with heatwaves, public service and infrastructure collapse, environmental pollution and transport accidents as a consequence of reduced visibility.

Table 6. Climatic and anthropogenic hazard interactions in Tenerife.

Hazard	**Risk level**	**Derived effects**	**Risk level**
Heatwave	High	Saharan dust Forest fires Critical infrastructure collapse	Moderate Very high High
Saharan dust	Moderate	Environmental pollution Critical infrastructure collapse Transport accidents	Low High Very high
Forest fires	Very high	Critical infrastructure collapse	High
Environmental pollution ([1])	Low	Critical infrastructure collapse	High

([1]) Only industrial environmental pollution is considered, i.e. other air pollution sources are not included, such as road transport.

Source: Cabildo de Tenerife, 2016.

More than 386,000 resident people are potentially exposed to these multiple hazards, and almost 59,000 are elderly people, i.e. 15% of the population under analysis (see Table 7). Most of the population that might be affected by these multi-hazards live in the metropolitan area (53%), although the touristic area is also relevant in terms of population (34%). The same can be said for elderly people: most of them live in the metropolitan area, followed by the touristic area.

Table 7. Population potentially affected by multiple hazards (year 2015).

Hot-spot	Municipality	Population	Elderly (>65)
Metropolitan area	Santa Cruz de Tenerife	203,811	36,215
Valley of Güímar	Arafo	5,499	1,012
	Candelaria	26,490	3,699
	Güímar	18,777	3,126
	Total	**50,766**	**7,837**
Touristic Area	Arico	7,327	1,313
	Arona	79,928	9,103
	Granadilla de Abona	44,846	4,376
	Total	**132,101**	**14,792**

Source: own elaboration based on ISTAC, 2016d and SIMAC, 2008.

Additionally, about 32,000 tourists live in a daily-basis in the areas considered as hotspots (see Table 8). Therefore, it could be argued that around 418,000 people might be vulnerable to the multiple hazards analysed in this case study, including both local and touristic population.

Table 8. Tourists potentially affected by multiple hazards (daily-basis, year 2015).

Hot-spot	Municipality	Beds available	Tourists ([1])
Metropolitan area	Santa Cruz de Tenerife	2,732	1,871
Southern Area	Arona	42,254	28,940
	Granadilla de Abona	1,193	817
	Total	**43,447**	**29,757**
Total		**46,179**	**31,628**

([1]) Own estimation based on the number of beds available and the island average occupation rate.

Source: own elaboration based on ISTAC, 2016b and SIMAC, 2008.

Once climatic and anthropogenic hazards have been exposed, the existing climate change adaptation-related policies in Tenerife will be reviewed in the next section.

2.5 State-of-the-art in climatic-related adaptation policies

The existing climatic and non-climatic related policies potentially useful for the case study can either be regional (i.e. covering the whole Canary Islands), or insular (i.e. only covering Tenerife). Moreover, these policies can either be directly focus on the hazards analysed here or indirectly. These policies are the next:

— Canary Islands scale:

1. Adaptation:
   - Canary Islands Climate Change Adaptation Plan (Martínez, 2010).
2. Civil Protection:
   - Civil Protection and Emergency Plan (Gobierno de Canarias, 1997).
   - Civil Protection against Extreme Weather Events Plan (Gobierno de Canarias, 2006).
3. Population Health:
   - Plan for the Prevention of Negative Effects of High Temperatures (Servicio Canario de Salud, 2006).
4. Air quality:
   - Clean Air Plan (SIMAC, 2008).
   - Clean Air Plan for Santa Cruz de Tenerife as a consequence of SO_2 (BOC, 2014).

— Island scale:

1. Civil Protection:
   - Disaster Risk Management Plan (Cabildo de Tenerife, 2012b).
   - Civil Protection and Emergency Plan (Cabildo de Tenerife, 2016).
2. Land-based Transport:
   - Land-based Transport Plan (Cabildo de Tenerife, 2012a).

In the next sections these policies will be briefly reviewed, in order to detect what specific measures are proposed to deal with heatwaves, Saharan dust events, air pollution, and possible hazards' interactions.

2.5.1 Heatwaves

The Canary Islands has available (although not passed into law) a specific plan for adaptation to climate change (Martínez, 2010). Two measures are proposed in this document so as to improve the resilience against heatwaves. On the one hand, the investment in Research & Development tools is proposed to predict what areas might be affected by heatwaves, as well as the localization of those areas by means of Geographic Information Systems. On the other hand, the use of information and educational campaigns to help inhabitants reduce heatwaves effects is also considered.

At regional scale, two civil protection plans intended to protect the islanders against natural and anthropogenic risks can also be cited (Gobierno de Canarias, 1997, 2006). The first plan assumes heatwaves as a natural risk that might occur in the Canary Islands, considering a series of measures to deal with all risks (Gobierno de Canarias, 1997). The most relevant measures established for heatwaves are:

1. Information campaigns through radio, TV and the Internet, so as to inform the public on the occurrence of potential catastrophic events, as well as potential self-protection actions that could be undertaken to reduce its effects.

2. Additional health assistance services if necessary.

3. Measurement of damages either on the population or infrastructure.

The second civil protection plan is specific to protect the islands against extreme weather events (Gobierno de Canarias, 2006). This plan establishes a series of measures for both the general public and the Island Councils. They are both presented in Table 9 (recommendations for the general public) and Table 10 (recommendations for decision-makers).

Table 9. Regional Government recommendations to the general public on heatwave protection.

Protect yourself from sunlight and drink water frequently
Stay at cold places as much as possible either outside or at home
Make use of blinds at home to avoid overheating
Open the windows during night
Make use of air-conditioning devises. If the devises are not available, visit Shopping Centres
Make use of either cups or hats, as well as light blank clothes
Walk on the shadow, stay under the umbrella in the beach and rest in fresh-air conditioned places
Never leave children and elderly people in the car
Avoid outdoor physical activities at mid-day
Eat fruits and vegetables, and avoid hot foods
Do not drink alcohol
Help other people: visit more frequent elderly people who are known to live alone
Consult the GP on the effects of medication during heatwaves
For other information, call the emergency number 0-12

Source: Gobierno de Canarias, 2006.

Table 10. Regional Government recommendations to the Island Councils on heatwave protection.

Protect yourself from sunlight and drink water frequently
Inform and warn decision-makers and other members of the Council
Pay attention to the meteorological forecast. Establish mechanisms of surveillance and information
Inform and warn those in charge of recreational areas so as to take proper actions if necessary
Warn the Council's environmental services of the current situation
Foresee the resources needed and its availability in advance
Guarantee wildfire prevention as well as a quick response against forest fires
Make use of Governmental information systems
Establish patrol and surveillance units to prevent forest fires
Cut off the circulation of roads affected by forest fires and inform the most affected populations
Assess the possibility to shut down activities (sport, schools, cultural,…)

Source: Gobierno de Canarias, 2006.

The Government of the Canary Islands has also available a plan for the prevention of the effects of high temperatures (Servicio Canario de Salud, 2006). This one is rather focused on population health. It is intended to activate levels of alert and provide specific additional services depending on the temperatures. Thus, "green" level means no risk. The "yellow" level is considered as "risk alert" when temperatures are above the threshold values for at least two days. In this level the health system should detect people at risk in order to provide appropriate attendance. The "orange" level is activated when the heatwave last three or four days at least. Meanwhile, the "red" level indicates that the heatwave is prolonged for more than five days and, apart from the provision of the previous additional services, the civil protection units may also be activated.

Lastly, at the Island scale of Tenerife, there also is a plan to prevent natural disasters using land-use planning strategies (Cabildo de Tenerife, 2012b). However, this plan neither deal with heatwaves, nor Saharan dust events, nor air pollution, since, according to the authors, these climatic and anthropogenic hazards cannot be coped with land-use actions.

2.5.2 Saharan dust events

The civil protection and emergency plan for the Canary Islands considers the intrusion of Saharan dust as a natural climatic hazard (Gobierno de Canarias, 1997). As mentioned above, this hazard is dealt with the same measures (1 to 3) proposed in the previous section (see section 2.5.1).

The adaptation plan for the Canary Islands proposes three measures to deal with Saharan dust events (Martínez, 2010). The first one highlights the need for Research & Development tools so as to have a better information system to predict and localize potential affected areas. The second measure is intended to create better warning system to provide population with information on how to reduce its potential impacts. Meanwhile, the last measure points out the necessity of implementing an analysis on how reduced visibility might affect transport infrastructure and transport service provision (air, maritime, and land-based transport).

There is another specific plan for civil protection at the Canary Islands scale (Gobierno de Canarias, 2006). This plan establishes a series of self-protection measures for the general public (see Table 11).

Table 11. Regional Government recommendations to the general public during Saharan dust events.

Protect yourself from sunlight and drink water frequently
Close the doors and windows at home. Avoid going out in case of chronic respiratory diseases
Be sure of having your medication at home
Drink as much water as possible and avoid the exposure to dry environments
Avoid physical activity during the event
In case of feeling unwell, visit your GP
In case of driving, pay attention to the road, turn on the lights and slow down speed

Source: Gobierno de Canarias, 2006.

2.5.3 Air pollution

The adaptation plan for the Canary Islands considers the implementation and upgrading of the current air quality surveillance system to prevent health-related impacts of air pollution (Martínez, 2010).

The civil protection plan for the Canary Islands presents environmental pollution as a specific technological associated risk linked to the refinery or power stations (Gobierno de Canarias, 1997). However, a more specific plan to deal with air pollution is presented in SIMAC (2008). This document establishes the areas affected by air pollution in Tenerife, the sources of pollution, and how they interact with the specific meteorological conditions. It also provides a series of specific measures to deal with the air pollution produced in the areas reviewed in section (2.3). These measures are twofold: transport-related and industry-related. Transport measures are focus on:

1. Technological improvement to guarantee a reduction in exhaust emissions while maintaining road transport traffic continuity.

2. Improving public transport.

3. Building park-and-ride infrastructure to ease the trespass from cars to public transport.

4. Switching off cars in congested roads.

Among the measures mentioned in SIMAC (2008) to manage industrial pollution (either from the refinery or the power stations) are:

1. Establishing an air pollution forecast system to analyse how the air pollutants behave once they are emitted into the atmosphere.

2. Shutting down certain production activities in the power stations when specific meteorological events occur.

3. Introducing technical and technological improvements to reduce the emissions of pollutants.

4. Using “cleaner” fuel.

Even though the SIMAC (2008) is a document covering the whole Canary Islands, the problems related to SO_2 in Santa Cruz de Tenerife, has made necessary to have a specific document for this pollutant in the capital city of Tenerife (BOC, 2014). Several measures are proposed, such as technical and technological improvements so as to reduce the emissions, as well as to incorporate, within the refinery, a Protocol that must be activated when certain meteorological conditions appear.

At the island scale, there is a land-based transport policy (Cabildo de Tenerife, 2012a) intended to increase transport sustainability and, therefore, reduce car emissions by means of the implementation of both railways and tram infrastructure ([6]). However, this policy also considers the expansion of road infrastructure across the island, which may induce new car trips (Marina and Marrero, 2012).

2.5.4 Multi-hazard policies

The climate change adaptation plan for the Canary Islands also considers several measures to deal with multiple hazards (Martínez, 2010). Concretely, the combined effects of heatwaves and air pollution episodes. Among the measures proposed are:

1. Encouraging public transportation systems.

2. The provision of walking and cycling infrastructure to reduce the effects of smog on local cities.

The civil protection plan against natural or anthropogenic-derived risks developed for Tenerife (Cabildo de Tenerife, 2006), proposes a certain number of measures (see Table 12). However, these measures are neither specific to deal with heatwaves, nor Saharan dust events, nor air pollution.

([6]) A critique to this land-based transport policy and a proposal of more sustainable options can be consulted elsewhere (Hernández, 2014; Hernández and Corral, 2016).

Table 12. Existing measures that might be related to climatic and non-climatic hazards.

Action	**Measure**	**Explanation**
Protection	Warning	Inform population regarding the emergency through local media
	Information	Inform population about self-protection measures
	Confinement	If necessary, inhabitants will be suggested to remain at home
	Health assistance	If necessary, first aid systems will be activated to attend human health
Intervention	Damage measurement	Damages will be assessed (on population, property, and environment)
	Risk assessment	The associated risks will be assessed as well as the area mostly affected
	Control and surveillance	The area affected will be followed-up
First aid	"Come to the aid"	People affected might be attended by sanitary workers or moved to hospitals

Source: Cabildo de Tenerife, 2016.

3 Material and methods: participatory integrated assessment for climate change adaptation pathways

Adaptation to climate change requires integrated approaches (EEA, 2016). According to Hernández and Corral (2016, p. 202), an integrated approach could be defined as «*the combination of existing and/or new methodologies intended to significantly improve scientific analysis of any complex issue*». These authors have identified that integrated assessment can be implemented either using technocratic approaches (where only experts define and propose solutions to specific issues) or by means of participatory processes (when not only experts but also stakeholders and the general community participate in the framing and problem solving). In Table 13 some examples of both approaches can be seen.

Adaptation to climate change is a recurrent environmental issue for the integrated assessment community, either for technocratic approaches (Cai et al., 2016; Krol and Bronstert, 2007; Paas et al., 2016) or for participatory ones (Andersson et al., 2015; Gain and Giupponi, 2015; Li et al., 2015; Melgarejo and Lakes, 2014; Rivington et al., 2007; Webb et al., 2013). Technocratic approaches are based on the combination of different sectoral models. They consist of the provision of a «*multi-level and interdisciplinary framework that brings together and synthesizes scientific knowledge from relevant disciplines*» (Ewert et al., 2015, p. 298). Thus, technocratic integrated assessment usually involve the combination of climatic and sectoral modelling that estimates biophysical impacts of climate change, along with economic models that translate biophysical impacts on macroeconomic indicators, such as prices, demand, supply, and Gross Domestic Product (GDP).

Several studies have implemented this approach. For example, Cai et al. (2016) analysed the expected economic impacts of climate change in South Asia by means of climate change biophysical impact models. Later on, this data is introduced in a computable general equilibrium model so as to estimate the economic loss in terms of GDP. Their conclusions indicated that adaptation to climate change is potentially useful to mitigate the expected impacts on the economy. Krol and Bronstert (2007) analysed the impacts of climate change on water scarcity in Brazil. By means of climatic, water, and agricultural models, the authors estimated potential population migration. Paas et al. (2016) applied similar approaches, in this case a bio-economic farm model, and concluded that this integrated impact assessment allowed for a better assessment of the potential improvement and variability among farms against climate change.

However, some authors have expressed their concerns about the implementation of technocratic approaches. Thus, for instance, Hertel and Lobell (2014) state that technocratic Integrated Assessments models might understate the impacts of extreme temperatures, meanwhile overstate adaptation capacity of poor countries' farmers. Nocera et al. (2014) have highlighted that the problem with technocratic approaches is that *«[t]he perspective of the society has not been taken into account adequately, thus leading to misunderstandings and conflicts between different perspectives because a real debate has been prevented and the positions tend to be polarized. This DEAD* ([7]) *approach favours decision-makers and postpones, or even omits, a real discussion with citizens*» (Nocera et al., 2014, p. 282).

([7]) Refers to Decision, Education, Announcement and Defence. These authors support decisions based on ADD (Announce, Discuss and Decide).

Table 13. Different case studies using integrated assessment for climate change adaptation policy governance.

Source	**Case study**	**Issue**	**Technical methods**	**Participatory methods**
Andersson et al., 2015	Gothenburg (Sweden)	Adaptation to heatwaves, floods, and air pollution	Life cycle analysis	Questionnaires, in-depth interviews, and focus groups
Cai et al., 2016	South Asia	Food production adaptation to climate change	Climate change impacts model, food production models, and computable general equilibrium model	---
Gain and Giupponi, 2015	Brahmaputra river basin (Bangladesh)	Adaptation of water resources systems	Multidimensional dynamic risk index	Questionnaires and interviews
Krol and Bronstet, 2007	Northeast Brazil	Adaptation to climatic variability and water scarcity	Climate, water, agriculture and socio-economic models	---
Li et al. (2015)	Poyang Lake (China)	Climate change adaptation for wetland sustainability	Multi-criteria analysis	Training workshops, household surveys, and progress review meetings
Melgarejo and Lakes, 2014	Chía (Colombia)	Adaptation to river floods	Multi-criteria analysis	Not mentioned
Paas et al., 2016	The Netherlands	Climate and socio-economic change on dairy farms	Bio-economic farm model	---
Rivington et al., 2007	Hartwood Farm (Scotland) and Agrichiana farm in Tuscany (Italy)	Climate change impacts on whole-farm systems	Bio-economic farm model	Workshops
Webb et al., 2013	Charters Towers (Australia)	Adaptation assessment for livestock industry	Multi-criteria analysis, forage production and farming enterprise models	Survey

Source: own elaboration.

From this perspective, participatory integrated assessment establishes that stakeholders should be considered in decision-making processes as powerful problem-solving tools (Banville et al., 1998), and also as basic requisites to cope with the complexities of the issues involved (Funtowicz and Ravetz, 1991, 1993). EEA (2016) considers that informing stakeholders is not enough in adaptation planning, it rather needs deep stakeholders' engagement (Kuik et al., 2016), in order to climb further up the ladder to levels of citizen power (Arnstein, 1969). Therefore, Kalaugher et al. (2013) have proposed to carry out integrated assessment using Mixed Models Frameworks for a better understanding of adaptation to climate change strategies, such as the combination of qualitative social research and quantitative biophysical modelling, so as to be benefited from the advantages of both.

Other authors mention that integrated assessment for adaptation to climate change need to include participatory processes, in order to look for solutions that reduce vulnerability and increase resilience not only in the short term, but also in the long-run (Gain and Giupponi, 2015). Andersson et al. (2015) mentioned that the involvement of public and stakeholders in integrated assessment approaches for climate change adaptation is a useful tool to propose possible measures, and assess strategies in order to make decisions implementable.

Gain and Giupponi (2015) have analysed water scarcity risks associated with climate change in Bangladesh by means of participatory integrated assessment approaches. They have assessed different adaptation options using a set of multidimensional indicators, as well as the values of stakeholders for the aggregation. The authors concluded that their participatory integrated assessment is a good basis for discussing water scarcity risks, as well as to identify indicators for the assessment.

An analysis developed in China concluded that participatory integrated assessment by means of multi-criteria analysis are particularly helpful to identify sustainability indicators, and the development of scenarios and climate adaptation actions to protect wetlands from climate change (Li et al., 2015). The same results has been found in Colombia for the analysis of river flood risks (Melgarejo and Lakes, 2014). By way of both participatory techniques and multi-criteria analysis, the authors proposed a series of alternatives to address the challenge of temporary shelter when river floods occur. Rivington et al. (2007) conducted an integrated simulation model along with stakeholders to assess climate change impacts on farming systems. The authors concluded that each approach reinforce each other, meanwhile the participatory process was used to define the topic and interpret the results.

Webb et al. (2013) also applied a participatory integrated assessment combining socio-economic modelling, multi-criteria methods and stakeholders' engagement techniques to evaluate adaptation strategies for graziers. The study highlighted that their integrated assessment enabled the proposal and recommendation of adaptation strategies that are relevant for stakeholders, being therefore more effective for their implementation. Lastly, stakeholder engagement and participatory processes in adaptation planning might boost social fairness (EEA, 2016).

This last participatory integrated assessment is the one applied in this case study. Its implications, development and steps will be presented below.

3.1 The participatory integrated assessment applied

There are three different adaptation approaches (EEA, 2016): (1) the «coping approach», which consist of coping with immediate impacts of extreme events once they have occurred; (2) the «incremental approach», which relies on the improvement of existing adaptation measures when dealing with extreme events; and (3) the «transformational approach», which establishes new and innovative solutions so as to increase society resilience to changes. In Table 14, the characteristics of each approaches are given. The cells in «green» refer to the characteristics in which the approach applied to the Tenerife's case study tries to rely on.

Table 14. Characteristics of different adaptation approaches.

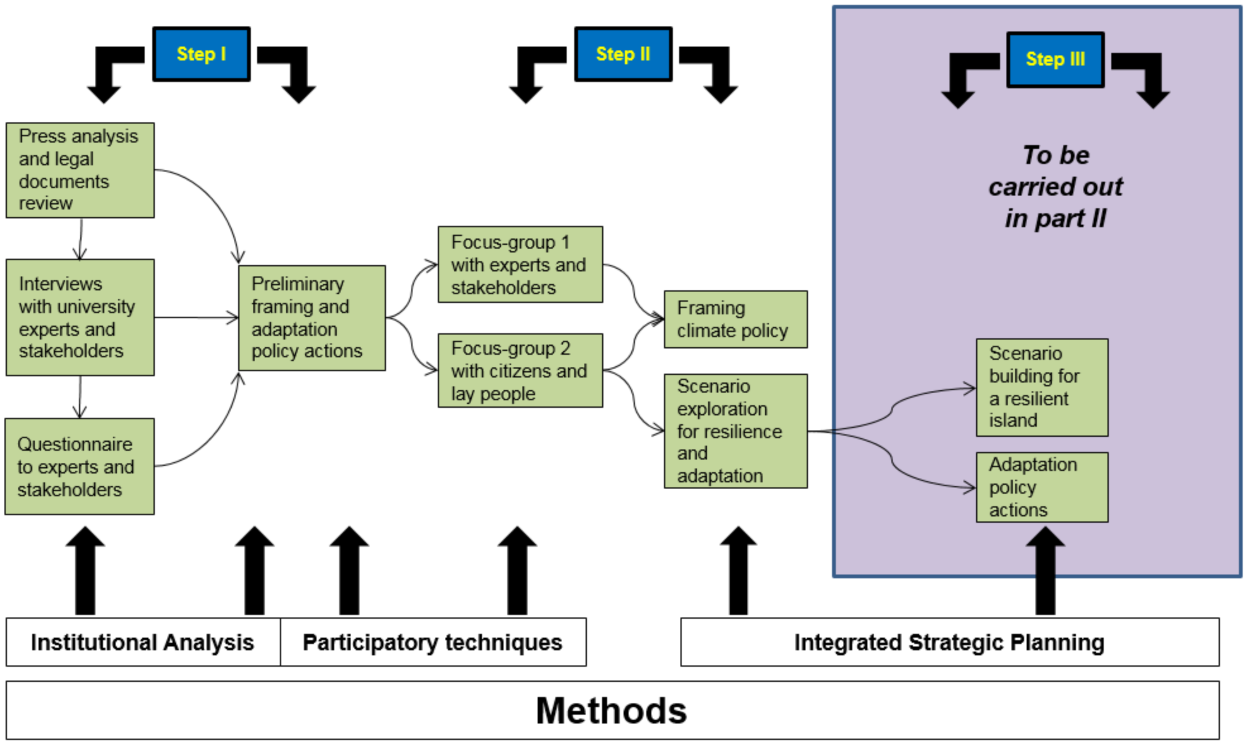
Characteristic	Coping	Incremental	Transformational
Aim	Restore quality of life and reduce disaster	Protect quality of life and prevent disaster	Improve quality of life under changed external conditions
Management	Reactive to change	Reactive to change	Planned of change
Time horizon	Short-term	Short to medium-term	Long-term
Planning	Disaster risk plan	Zoning plan	Sustainability programme
Participation	Action-focused stakeholder involvement (mostly of professionals)	Project-focused involvement of stakeholders	Broad and integrating involvement of stakeholders in planning
Scale/integration	Sectoral and local	Mainly sectoral and local	Integrated across sustainability planning
Flexibility	Moderate	Low to medium	High
Risk of maladaptation	High	Medium	Low
Risk of human and economic looses	High	Medium	Low
Unsustainability	Possible lock-ins into unsustainable pathways	Possible lock-ins into unsustainable pathways	Avoid lock-ins into unsustainable pathways
Uncertainty	Ignored	Partly deal with uncertainty	Deal with uncertainty
Dealing with change	Change seen as a risk	Change seen as a risk	Change seen as an opportunity
Use of technologies	Known and trusted	Known and trusted	Innovative solutions

Source: adapted from EEA, 2016.

The «transformational approach» desired to be put into practice in this case study is based on the methodologies shown in the scheme presented in Fig. 10 (in green). As seen, the scheme was prepared to be developed in three steps, although this part I will only perform the first and second stages.

Experts and stakeholders were involved from the very beginning of the process so as to preliminary frame the issue as well as propose potential adaptation policy actions (step I). Secondly, in a step II, focus group sessions were implemented in order to deeply discuss and frame the *problematique*, not only with experts and decision-makers, but also with local citizens and lay people. Citizens affected by heatwaves, Saharan dust events and air pollution, as well as citizens interested in climate change policy were addressed. The last step III still needs to be carried out (see section 5.2). In the next section, and explanation and literature review of each step (I and II) will be given.

Figure 10. Scheme of the proposed participatory integrated assessment



Source: own elaboration.

3.2 Step I: institutional analysis and participatory techniques

Institutional analysis should be considered as a fact-finding procedure to examine different structures and social relationships (Corral, 2004), providing a more precise approximation to the prevailing social and institutional arrangements, assumed as a social context shaped by institutions that delimit citizens' rights and responsibilities (Bromley, 1989; Commons, 1961; Schmid, 1972).

Institutional arrangements have been considered important for the understanding of climate change adaptation strategies. Thus, severity of heatwaves, in terms of either intensity or frequency, shape institutional arrangements among interest parts (Eisenack, 2016). Other studies have detected that even though the synergies between mitigation and adaptation to climate change are underpinned in legislation, the interpretation of that pieces of legislation does not consider these synergies, leading to isolated analyses and missed opportunities (Larsen et al., 2012). It has also been said that small islands tend to be more resilient as a consequence of dense social networks, such as collective action, reciprocity, and relations of trust, being all this particularly relevant for climate change adaptation (Petzold and Ratter, 2015). Other studies detected lack of coordination among institutions leading to a reduced adaptation capacity (Storbjörk and Hedrén, 2011).

Institutional constraints are also relevant to understand the associated complexities of climate change adaptation. An analysis conducted in the Netherlands for agriculture adaptation, concluded that the heterogeity of actors' interests on the one hand, and the availability of resources on the other, were two relevant obstacles to implement adaptation measures (Mandryk et al., 2015). In effect, local power structures do shape adaptation decision-making. Næss et al. (2005) detected that when powerful stakeholders coincide in the necessity of adapting to climate change, adaptation measures are quickly implemented. Furthermore, Næss et al. also argue that local institutional relations and power structures act like filters of new currents in adaptation so as to slow down the process of community learning.

Theoretical aspects of institutional analysis either to justify the necessity of these approaches (Ostrom, 1990, 2005) or suggest guidelines (Ingram et al., 1984) or frameworks of analysis (Imperial, 1999; Koontz, 2006) have been discussed. Institutional analysis is generally carried out through the employment of diverse social methods and participatory approaches. Thus, in the present research, a historical review of the local and regional press articles and legislation, together with an in-depth round of interviews allowed framing the social and political context in which climate change adaptation in Tenerife is embedded. In this sense, institutional analysis enables an evolutionary analysis of the role and standpoints of each stakeholder, providing a map of the relevant stakeholders and their positions. Thus, the information that could be collected through institutional analysis implemented in Tenerife is presented in Table 15.

Table 15. Potential information that could be collected from experts and stakeholders.

Framing	A definition of the *problematique* at hand Existing climate change policies Stakeholders' objectives and strategies (e.g. hidden agenda) Uncertainties
Proposal of stakeholders	Each stakeholder recommends the inclusion of other key social actors
Preliminary proposal of policy packages	Potential policy options for adaptation Obstacles to the implementation of those policy options
Preliminary proposal of evaluation criteria	Indicators to evaluate policy packages

Source: own elaboration based on questionnaires and in-depth interviews.

The first part developed in step I is the press review. Next section is aimed at presenting this institutional analysis method.

3.2.1 Press review

It consists of the review of the local press that make reference to the case study. According to Corral (2004), it is a valuable source of information since it allows for a wider an objective view of the issue; wider because different opinions are seen; and objective since it helps the analysts to approach the issue from different perspectives. This social technique has been successfully applied to different integrated assessment case studies, such as air quality policies (Corral, 2004), water resources management (De Marchi et al., 2000; Paneque et al., 2009), and sustainable mobility policies (Hernández, 2014; Hernández and Corral, 2016).

For the purpose of this case study, local press analysis has allowed the analysts for the possibility to access the next sources of information:

— **Framing**. It could be seen that heatwaves and Saharan dust events are a frequent climatic phenomena in the Canary Islands. Moreover, local experts in climate change were identified, and indicated that there are relevant policy gaps and a lack of multi-risk policy foresight in the Island (see section 2.5). Air pollution is not so deeply covered by the media, even though there are severe problems related to this (as seen in section 2.3). However, some media press articles have reported increasing mortality and overuse of medical services, as a consequence of increasing morbidity.

— **Identification of experts and relevant stakeholders.** A certain number of local experts in climate change and relevant stakeholders have been detected through the local media, allowing for potential contacts to be considered for the next participatory techniques.

Once a preliminary group of stakeholders were identified, an in-depth round of interviews were conducted.

3.2.2 In-depth interviews to experts and stakeholders

In-depth interviews to experts and stakeholders have been considered appropriate to implement institutional analyses (De Marchi et al., 2000; Paneque et al., 2009). Initially, experts are interviewed first (Corral, 2004) in order to have a preliminary list of stakeholders to be engaged and contacted (Hernández, 2014). Thus, experts are usually «used» as «keys» that «open» certain «doors» that otherwise cannot be «opened». Then, once all relevant stakeholders were identified, they were contacted by phone.

By means of open questions, relevant information is collected, such as policy gaps, new alternative policy options, and evaluation criteria (Corral, 2004; Guimarães et al., 2003; Paneque et al., 2009). In the present case study, in-depth interviews have been used to frame the issue, to collect existing reports and scientific publications on the issue, to propose adaptation policy actions, as well as to map the positions of the stakeholders regarding the issue under analysis.

A part from the in-depth interviews, a questionnaire was also conducted in order to collect more precise information, as well as to analyse how coherent the stakeholders are when asked the same questions through different means.

3.3 Step II: focus groups

Morgan (1996, p. 130) defines focus groups «*as a research technique that collects data through group interaction on a topic determined by the researcher*». It has also been defined as a social event (Bloor et al., 2001) or a form of group interviewing (Gibbs, 1997) that pursues the collection of qualitative information intended to answer research questions (Morgan and Krueger, 1993). It helps the researcher to detect attitudes, feelings, beliefs, experiences, and reactions that would not be collected by other social research method (Gibbs, 1997; Kitzinger, 1994).

Focus groups have been considered useful tools to learn more about the degree of consensus of a certain topic, as well as the opinion of the stakeholders involved, and their reasons to answer certain research questions (Morgan and Krueger, 1993). Focus groups are also useful to collect information on tensions between opposing parties (Kitzinger, 1994; Morgan and Krueger, 1993). However, when the parties are too polarised, the focus group might not work adequately (Hernández, 2014). Similarly, focus groups might be appropriate to shed light on uncertainties and ambiguities related to the issue at hand (Bloor et al., 2001), being an effective and economical way to collect relevant information in a short period of time (Gibbs, 1997).

For all these reasons, focus groups have become attractive techniques for citizen participation, since they are flexible tools that can be used at any step of a decision-making process (Bloor et al., 2001). Moreover, they have also been considered flexible tools since groups can be sorted, for example, by age (Guimarães and Funtowicz, 2013). Just to mentioned some examples, focus groups has been applied to improve governance of water resources (Guimarães et al., 2005; Paneque et al., 2009), to assess windfarm location (Gamboa and Munda, 2007), and sustainable mobility policies (Hernández and Corral, 2016). However, it has to be noted that focus groups are not representative of what the community think about a certain issue (Gamboa and Munda, 2007); it is rather a social research method (Bloor et al., 2001; Morgan and Krueger, 1993).

Focus group sessions should be composed of 6 to 8 participants in order to have an optimum size (Bloor et al., 2001). Although other authors mention that the group might be between 6 and 15 participants (Kahan, 2001). In the literature, shorter number of participants (five) can be found (Gamboa and Munda, 2007), as well as larger (eighteen) (Hernández and Corral, 2016). Too short number of participants could end with limited discussion, whilst too large groups might be difficult to moderate, might reduce adequate time to express stakeholders' points of view, or might give room to several stakeholders to monopolise the discussion (Kahan, 2001).

In the current analysis, four focus group sessions were carried out in order to:

1. Frame the issue at hand, i.e. is climate change perceived as a risk in Tenerife? Is there a lack of climate change adaptation policies in the island?

2. If so, what can be done to increase the island resilience?

The first focus group was organised to gather all experts in climate change, stakeholders interested in climate change adaptation, and local decision-makers. This first session was rather technical and followed the Agenda shown in Annex II. The second series of focus groups consisted of three sessions with local citizens. During each session, invented newspapers (referring to Tenerife in 2040) were presented to the citizens. These invented newspapers described an extreme climate change scenario (see Annex III). This exercise was used to carry out three tasks along with the attendees:

1. How they might be affected by a hypothetical extreme scenario (so as to have a framing or understanding of local climate change perceptions).

2. What images they have for Tenerife in 2040, assuming that the world has entered in a new era of climate reality (WMO, 2016).

3. What specific actions might be implemented to adapt Tenerife to that reality?

4 Results: implementing steps I and II

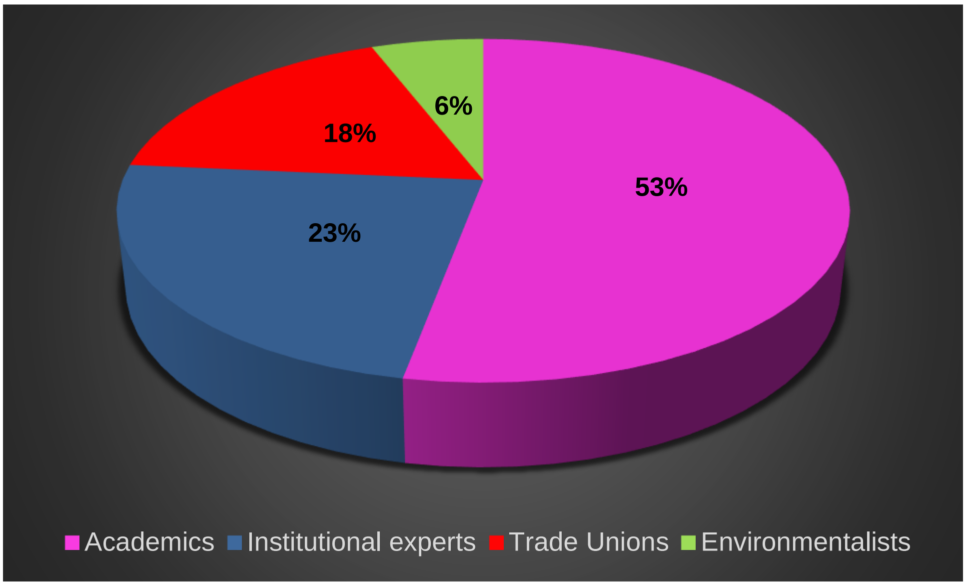
The results of the analysis will be presented following the scheme presented in Fig. 10. As seen, it consists of the two steps.

4.1 Step I. Institutional analysis: framing climate change in Tenerife

4.1.1 Stakeholders participating in the in-depth interviews and a questionnaire

There were different groups of stakeholders that have participated. The first group is comprised of experts in climate change (either Universities or Research Centres), decision-makers (from the Government of the Canary Islands and the Council of Tenerife), trade unions (both national and local), and environmentalist groups. Then, the proportion of participants by groups can be seen in Fig. 11.

Figure 11. Scheme of the proposed participatory integrated assessment



Source: own elaboration.

These groups of stakeholders were not the only ones invited to participate. In fact, the number of invited groups were much larger and plural than those who finally participated. However, for several reasons, some stakeholders decided not to participate. They were:

— An expert who works for the Hospital of Tenerife, specialised in cardiology. He answered the official letter but declared to have a tight agenda to attend any participatory process.

— Municipalities' organization (FECAM). They answered the invitation letter, but did not respond neither the questionnaire nor attended the first focus group session.

— Employers' organization (CEOE): They declared not to have a person in charge of environmental issues. Therefore, preferred not to participate.

— State company specialised in technological and renewable energy appliances (ITC). They could not attend the participatory process since this company is currently having financial problems.

— One local environmental group (Ben-Magec). They did not answer the official invitation letter.

In the next paragraphs a brief presentation of the participants is given:

Academics

— **United Nations Office for Disaster Risk Reduction**: the correspondent is an expert in climate change mitigation and adaptation policies with emphasis in urban planning, renewable energy resources and climate change initiatives. This expert has collaborated with the University of La Laguna in the development of policies for increasing resilience in the Canary Islands. This expert is currently working on projects for resilience in the island of Lanzarote (the western Island of the Canaries).

— **Izaña Atmospheric Research Centre**: two experts have participated from this research centre. The first one, Director of the Research Centre, is an expert of the Global Atmospheric Watch Programme, dust storms, meteorology and climate change in the Canary Islands. The second expert is, on the other hand, specialised in atmospheric aerosols, Saharan dust and air quality. The latter is currently working on projects on the effects of ultrafine particles in human health.

— **Department of Mechanical Engineering of University of Las Palmas de Gran Canaria**: this expert is a senior university professor well known in the Canary Islands for contributing to sustainable development projects, as well as renewable energy development plans.

— **Institute of Tropical Diseases and Public Health of University of La Laguna**: this expert is a senior university professor specialised in vector-borne diseases, who is currently working on different projects to analyse the effects of climate change on the arrival of potential vector-borne diseases to the Canary Islands.

— **Department of Geography of University of La Laguna**: this expert is a senior university professor who is skilled in resilience and disaster risk management plans, as well as in local climatology, Saharan dust events and aerosols.

— **Department of Physics of University of La Laguna**: this expert is a senior university professor specialised in atmospheric aerosols who is currently working on high-definition climatic models that might be useful for the specific micro-climates of the Canary Islands.

— **Department of Ecology of University of La Laguna**: this expert is a senior university professor specialised in ecology, and head of the Island Ecology and Biogeography Research Group, who is at this time working on forest dynamics, restoration ecology, impacts of forest fires, and exotic species.

— **Teide National Park**: he is currently researching on global warming issues in the Teide National Park. This expert is also skilled in conservation biology, climate change, and management of protected areas.

Institutional experts

— **Department for Pollution Prevention of the Canary Islands**: the correspondent is the Head of the Department, who is in charge of environmental pollution prevention. This Department has developed both air quality plans for the Canary Islands and Santa Cruz de Tenerife.

— **Department for Public Health of the Canary Islands**: the correspondent is the Head of the Department in charge of risk assessment, who is also in charge of developing the air quality plans for the Canary Islands and Santa Cruz de Tenerife.

— **Department for the Environment of the Council of Tenerife**: the correspondent used to be the Director of the shut down Climate Change Agency of the Canary Islands. This correspondent was in charge of developing the Climate Change Adaptation Plan.

— **Department for Civil Protection of the Council of Tenerife**: the correspondent is in charge of this Department, as well as the development of the two existing plans on civil protection and disaster risk management for Tenerife.

Trade Unions

- **National Trade Union (CCOO)**: the correspondent is in charge of environmental issues, and used to be a member of an environmental NGO.
- **National Trade Union (UGT)**: the correspondent is in charge of workplace risk prevention, and has knowledge about working conditions, especially when extreme weather events occur.
- **Local Trade Union (Intersindical Canaria)**: the correspondent is in charge of health issues, and has knowledge about doctors and nurses conditions in the public hospitals of Tenerife.

Environmental NGO

- **Local environmentalists (ATAN)**: this is a local environmental group with a long history in Tenerife. They have been defending the natural heritage of Tenerife, as well as the promotion of sustainability projects for the Island.

4.1.2 Stakeholders' opinions on the issue and the existing policies

In the next two tables, stakeholders' opinions are given regarding both the issue under analysis (Table 16), i.e. the effects of heatwaves, Saharan dust events, and air pollution, and their opinion on the usefulness of the existing policies (Table 17).

Table 16. Stakeholders' opinions on the issue at hand.

Stakeholder	Opinion
University experts and others	
Teide National Park	Temperatures are increasing in general, but in the Teide National Park much more than the global average. Thus, while global temperatures have increased 0.8 degrees, in the Teide National Park 1.5 degrees warming have been reported. Regarding the issue at hand, several scientific articles indicate that heatwaves might be increasing in the Canary islands, as well as Saharan dust events in winter time
Department of Geography (University of La Laguna)	There are some partial studies indicating that heatwaves, Saharan dust events, and air pollution are impacting on human health. It is however not clear that these hazards are becoming frequent as a consequence of climate change, although some climatic models are indicating that the intensity of these hazards are increasing
Department of Physics (University of La Laguna)	Direct data on the combined effects of these hazards is not available. Neither could I sustain that heatwaves are becoming frequent, even though it is the general impression. First of all, heatwaves and Saharan dust events have impacts per se on human health. In fact, the hospitals are negatively affected as a consequence of increasing peak demand. Local ecosystems are also affected. Aerobiological threats could also be a consequence of climate change, e.g. potential virus and bacteria are reaching the Islands as a consequence of changes in wind patterns. These vector-borne disease might have impacts on human health
Department of Ecology (University of La Laguna)	First of all, industrial air pollution is very low in the islands, since the Canaries are not industrial economies. The pollution that comes from the European continent is also low, since it gets purified across the Atlantic ocean. Therefore, industrial air pollution is not relevant. However, road transport may be a problem, although the Northern winds export most of the pollution produced by land-based transport activities. Then, this case is not relevant either. Secondly, Saharan dust events are not significant either, since they have always been occurring in the past. Besides, this dusty weather events are beneficial for the ecosystems as a consequence of the natural fertilizer effect produced by phosphorous additional applications. Therefore, this other hazard is not important either. Nevertheless, heatwaves are really problematic, as well as the increasing temperatures and decreasing rainfall. Heatwave hazards might recreate the environmental conditions for the spreading of exotic species across the islands: exotic species that are about to arrive or have already arrived but are still marginal in parks and gardens. However, in terms of environmental hazards, the most important issue is not external (such as global warming), but internal: it comes

	from our own economic model which is based on an ever increasing infrastructure of any kind, such as hotels, golf courts, airports, ports, roads, etc.
Institute of Tropical Diseases and Public Health (University of La Laguna)	Climate change might generate health problems by means of bacteria, strain and viruses arrival. A study is about to be published on the effects in the Islands of aero-transported bacteria under Saharan dust events. Increasing bacteria resistance to antibiotics have been detected. Moreover, increasing temperature boost vectors by means of mosquitos, due to warming climates reduce its reproduction cycle by a third (i.e. the number of mosquitos can be multiplied by a factor of three). Therefore, increasing temperature might either lead to, on the one hand, the arrival of new vector-borne diseases that does not exist in the Islands or, on the other hand, the reproduction of suitable environments for the spreading of already existing vector-borne diseases, or both. All this may have a negative impact on human health
Department of Mechanical Engineering (University of Las Palmas de Gran Canaria)	It is neither sure that heatwaves are becoming frequent, nor that heatwaves are co-related to air pollution episodes. However, heatwaves might have negative impacts on several groups of population, ecosystems, increasing use of energy and power stations
United Nations Office for Disaster Risk Reduction	Heatwaves, Saharan dust events, and air pollution are producing impacts in Tenerife. In terms of air pollution, Tenerife and Gran Canaria are the most affected Islands. Saharan dust events produce impacts on population health, especially those with chronic diseases. Among these health effects we may find itchy throat, itchy eyes, asthma, and breathing problems. In fact, there are people that cannot leave their homes under Saharan dust events in order to prevent negative health effects
Izaña Atmospheric Research Centre	
Expert in climate and meteorology	Heatwaves, Saharan dust events, and air pollution produce impacts on population health. What is currently unknown is if, under a scenario of climate change, those hazards will worsen or not. What it is however appreciated is that the African continent is warming and Northern Africa is getting drier. It is also unknown the evolution of key meteorological systems over North Africa (the North African anticyclone and the Saharan Heat Low) that constitute a triggering factor for hot air and Saharan dust transport from North Africa to the Canary Islands. In terms of air pollution, Santa Cruz de Tenerife is clearly affected by three activities, which are the refinery (currently shutdown), road and ship transport. Then, the mixture of Saharan dust events and local air pollution from these sources might have serious impacts for several days a year mainly in winter/early spring time when dust outbreaks impact lower levels of the island.
Expert in air quality	Negative effects of both Saharan dust events and air pollution on population health are generally assumed. There are several epidemiological studies highlighting these negative effects. However, heatwaves and Saharan dust events do not necessarily occur simultaneously; in fact, most

	heatwaves in summertime occur under high stability, low temperature-inversion, high sea surface temperatures, and air stagnation conditions, sometimes, following Saharan intrusions. The Izaña Atmospheric Research Centre has been working these last years with a group of cardiologists and negative effects of ultrafine particles and black carbon on cardiovascular responses have been reported. Currently, the Izaña Atmospheric Research Centre is working with pulmonologists. Their analyses came across with some correlations between the exposure to Saharan dust events and Chronic Obstructive Pulmonary Diseases
Government of the Canary Islands	
Department for Pollution Prevention	The Canary Islands are generally affected by African particle matter, producing negative effects on population health. It cannot be suggested that either heatwaves or Saharan dust events are becoming frequent. However, some studies are mentioning that climate change could trigger more heatwaves and Saharan dust events in the Islands. In terms of local air pollution, it is also known that ultrafine particles coming from local sources are impacting on human health
Department for Public Health	No opinion
Council of Tenerife	
Department for the Environment and Landscape	It seems that Saharan dust events have been increasing in the last decades, especially in winter time. According to some studies, air pollution in Santa Cruz de Tenerife might exceed the limits when local background pollution interact with Saharan dust events, leading to negative effects on local populations. Currently, as a consequence of the refinery shutdown, air quality has remarkably improved in Santa Cruz de Tenerife. It is not however clear the impacts on the environment, except forest fires that are closely related to heatwaves. Saharan dust events reduce ecosystems humidity, increasing wildfire risks. Moreover, some positive impacts have also being reported, such as the creation of protosoils for some types of vegetation as a consequence of Saharan dust depositions
Department for Civil Protection	Heatwaves are caused by certain meteorological conditions in the Canary Islands that are related to Saharan meteorological events (such as atmospheric stability, thermal inversion, and low ventilation). However, heatwaves do not trigger air pollution. Saharan dust events, atmospheric stability, low ventilation, and thermal inversion are related to air pollution but the intensity is not known. Air pollution impacts are produced in the metropolitan area, especially in Santa Cruz de Tenerife, as a consequence of its orography, local wind, high volume of traffic and industrial activities (the refinery, although it is currently shutdown). All in all, the most relevant impact is derived from heatwaves and forest fires

Trade Unions	
National scope (CCOO)	The potential negative effects produced by the combination of heatwaves, Saharan dust events, and air pollution require a deep scientific analysis. It is however known that these hazards have been producing impacts on population health as separate hazards. However, their combination need to be analysed, since climate change might trigger more frequent Saharan dust events
National scope (UGT)	Heatwaves and Saharan dust events are becoming more frequent. However, these climatic hazards cannot be dealt with at local scale. That is, global problems should have global solutions. Regarding air pollution, a reduction of around two thirds in the concentration of toxic particles has been noticed in Santa Cruz de Tenerife after the refinery shutdown, which is one of the oldest refineries in Europe. This relevant air pollution reduction should make us think that all the efforts at legislative scale have not been able to reduce air pollution in such levels. When these climatic and non-climatic events occur, the Hospitals collapse as a consequence of the combination of peak-demand periods and staff cuts due to the economic crisis. Among the most affected people are children (between 4 and 10 years old) as well as the elderly with previous chronic diseases
Local scope	Generally speaking, the economic model developed in Tenerife is essentially destructive. Public policy is based on the construction of new infrastructure, especially roadways. Car usage is comparable to continental big cities, and alternative modes of transport have been constantly discriminated. Apart from the local pollution and the destructive economic model, when Tenerife suffers extreme climatic events, such as heatwaves and Saharan dust, people with chronic diseases are negatively affected (especially by Chronic Obstructive Pulmonary Diseases), increasing Emergency demand at Hospitals. Currently, the health system is already under collapse as a consequence of budget cuts and staff reduction. Therefore, under extreme climatic events, the situation at Hospitals get worse, even beyond collapse
Environmental NGOs	
Island scope	The combination of heatwaves, Saharan dust events, and air pollution is a very serious problem. Heatwaves and Saharan dust events are becoming frequent and they both are negatively impacting on the local ecosystems in terms of changes in its distribution. Regarding impacts on human health, these hazards are also notorious. It would only be a matter of developing an epidemiological study to realise how serious this is. Air pollution has improved in Santa Cruz de Tenerife as a consequence of the refinery shutdown

Source: own elaboration based on in-depth interviews.

Table 17. Stakeholders' opinions on current policies.

Stakeholder	**Opinion**
University experts and others	
Teide National Park (Council of Tenerife)	Adaptation is not usually considered in the existing plans for climate change. Actually, there are plans for most of the environmental problems, however, they are not useful at all for adaptation to climate change. Lot of work in adaptation is still needed. Risk and vulnerability analysis have already been analysed, but there are not specific action plans
Department of Geography (University of La Laguna)	Regarding heatwaves, Saharan dust events, and air pollution, the current adaptation plan is old-fashioned and unused. The existing plans for civil protection are focused on floods and extreme rainfall, and most of them do not consider climate change in a scientific way. More efforts on risk reduction instead of civil protection is needed
Department of Physics (University of La Laguna)	The Canary Islands are characterised by specific micro-climates that might bring a sunny day in one part of the island at the same time it can bring extreme weather events just a few kilometres away. Therefore, any adaptation plan for the Canary Islands should be based on specific and high-resolution climatic models. The current adaptation plan has been however based on continental climatic models. This is not valid
Department of Ecology (University of La Laguna)	Generally speaking, not much have been done in terms of environmental public policies
Institute of Tropical Diseases and Public Health (University of La Laguna)	Increasing risks of vector-borne diseases coming from North Africa, by means of Saharan dust and heatwaves events have not been yet considered in policy-making. Although, some specific measures have been implemented in ports and airports to prevent the arrival of vector-borne diseases. Nevertheless, more analysis should be carried out to estimate the impacts of climate change in the Canary Islands, especially in terms of vector-borne diseases
Department of Mechanical Engineering (University of Las Palmas de Gran Canaria)	Generally speaking, there is no reliable planning in the Canary Islands. An integrated sustainable development plan is still needed
United Nations Office for Disaster Risk Reduction	Nowadays, there is a dispersion of different plans and sometimes they are unnecessarily overlapped. There are cases where several plans could have been integrated altogether

Izaña Atmospheric Research Centre	
Expert in climate and meteorology	Most of the policies should address cities where live most of the population. For example, the effect of heatwaves in summer could be attenuated, in part, through green urbanization of cities, implementing smart-plans that include shade trees plantings and awnings placement in order to reduce pavement and parked vehicles heating. These are the elements that increase significantly air temperature locally by emitting more infrared radiation when exposed to the sun. Improving mobility by decisively stimulating public transport and hindering the use of private vehicles would significantly improve air quality and reduce locally temperature (especially in summer), significantly improving the quality of life of large cities inhabitants. As far as I know, none of these actions are being taken.
Expert in air quality	No opinion
Government of the Canary Islands	
Department for Pollution Prevention	The existing plans for air quality have been elaborated in our Department. They are not focused on climate change issues, but on anthropogenic air pollutant emissions. Regarding the existing plan for climate change adaptation in the Canary Islands, it is not approved yet. Furthermore, the climate change adaptation plan does not consider specific measures to deal with climatic hazards. Potential impact assessment of climate change in the Canary Islands is available, but adaptation has not properly been considered. However, the existing current plans might be considered as a cornerstone that needs to be developed in the future. In terms of climate change and public health, not much information is available
Department for Public Health	No opinion
Council of Tenerife	
Department for the Environment and Landscape	All these plans have different scopes. First of all, adaptation plan has been developed with a long-term point of view, and it was focused on infrastructure adaptation to a changing climate. This plan is not approved but it should be approved and implemented. Secondly, the air quality plans for the Canary Islands and for the metropolitan area of Tenerife are intended to reduce air pollution. These two air quality plans consider Saharan dust events. Furthermore, these two air quality plans should be updated to improve air quality in the metropolitan area. Lastly, the existing plans for civil protection should be modified to include the combination of Saharan dust events and air pollution episodes as climatic and anthropogenic hazards. However, all these plans, if upgraded and implemented, are more than enough to adapt to climate change

Department for Civil Protection	Regarding civil protection, these plans have been coordinated in this Department. The existing disaster risk management plan for Tenerife does not have any relation to neither climate change nor adaptation to heatwaves, Saharan dust events, nor air pollution. This plan was intended to mitigate the expected effects of natural disaster by means of land-use planning. Therefore, this plan does not cope with any hazard that cannot be mitigated through land-use planning. The same can be said for the plan for civil protection of the Canary Islands. In fact, in case of heatwaves and Saharan dust events, this plan is only able to provide suggestion to the population to reduce the exposure to both climatic events, but nothing more. They are, however, useful for flood protection and strong winds. Generally speaking, the existing current civil protection plans are neither sufficient to deal with heat waves, Saharan dust events, and air pollution, nor their potential interactive effects. All in all, some of these plans contribute few or nothing at all to adapt to climate change or the hazards analyse here
Trade Unions	
National scope (CCOO)	These plans may have a positive impact for adaptation to climate change, as well as to reduce air pollution. However, research on climate change impacts and its effects need to be boosted
National scope (UGT)	These plans should have been developed in a more participatory way, including key stakeholders. Furthermore, these plans should be implemented within private companies, in order to increase the resilience against climatic and non-climatic hazards across all economic sectors
Local scope	Most of these plans exist due to they are mandatory either by the European Union or by the State, otherwise they would have not been developed. Furthermore, most of them are good plans, but they are not implement and sometimes even ignored
Environmental NGOs	
Island scope	These plans are insufficient since in most cases they do not deal with the cause of the problems. For example, massive private car use is the cause of air pollution, apart from other sources like the refinery (currently shutdown) and the aerosols coming from Africa. These plans are only intended to make people believe that politicians are taking action against certain problems, but nothing more. However, real specific measures have not been implemented to mitigate climate change

Source: own elaboration based on in-depth interviews.

4.1.3 Differences in stakeholders' opinions

The stakeholders consider that heatwaves, Saharan dust events, and air pollution are certainly impacting on population health and the local environment (as seen in section 2), however only as isolated hazards. Thus, one of the hypothesis suggested in this case study (i.e. the potential negative effects of the combination of heatwaves, Saharan dust events, and air pollution) is not so clear according to the stakeholders.

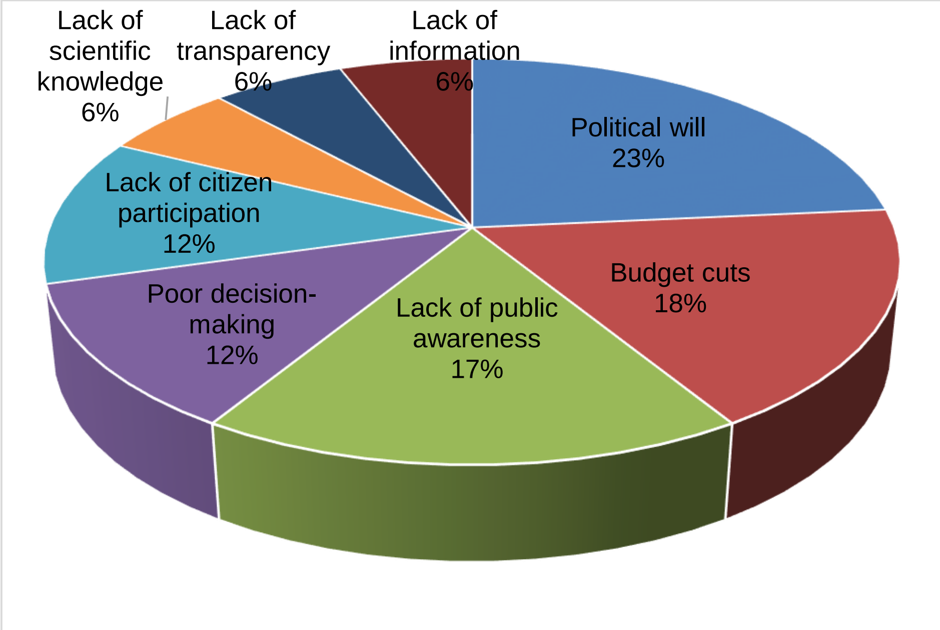
For example, one first conflict opinion regards the hypothesis that heatwaves and Saharan dust are connected climatic events. The representative of the *Institute of Tropical Diseases and Public Health* stated that these two climatic events occur together in the Canary Islands, whilst an expert of the *Izaña Atmospheric Research Centre* indicated that both events do not necessarily have to occur simultaneously, but sometimes stable weather conditions after a Saharan dust event favour heatwaves.

Secondly, another relevant divergent opinion concerns the frequency of heatwaves and Saharan dust events. Most of the academics (e.g. from the *Department of Geography* and the *Department of Physics of the University of La Laguna*, the *Department of Mechanical Engineering of the University of Las Palmas de Gran Canaria*, and the *Izaña Atmospheric Research Centre*), as well as some institutional experts (from the *Department for Pollution Prevention of the Government of the Canary Islands* and the *Department for Civil Protection of the Council of Tenerife*) declared that the increasing frequency of heatwaves and Saharan dust events are not totally clear. Whilst, other institutional experts and stakeholders (the *Department for the Environment and Landscape of the Council of Tenerife*, the *local environmental NGO*, and one national trade union) declared to believe that these climatic hazards are becoming frequent.

Another remarkable divergent opinion came out regarding two issues: the impact of air pollution and Saharan dust events on human health. According to the representative of the *Department of Ecology of the University of La Laguna*, neither air pollution nor Saharan dust events could be considered relevant problematic issues in Tenerife. Several academics and institutional experts disagree with this statement, such as both representative of the *Izaña Atmospheric Research Centre*, as well as the representative for the *Department for Pollution Prevention of the Government of the Canary Islands*, who considered ultrafine particle and black carbon emissions a serious problem on the development of cardiovascular diseases in Santa Cruz de Tenerife (this has also been discussed in section 2.3). Moreover, the representative of the *Izaña Atmospheric Research Centre* and the one from the *United Nations Office for Disaster Risk Reduction* contemplate that Saharan dust events produce impacts on human health such as chronic obstructive pulmonary diseases (see also section 2.2). Furthermore, the representative of the *Izaña Atmospheric Research Centre* stated that the combination of Saharan dust events and local air pollution may be a serious episode several days a year in Santa Cruz de Tenerife.

Another final divergent opinion appeared when the stakeholders were asked to point at the responsible of the current situation. As seen in Fig. 12, different opinions were elicited: most of the stakeholders blamed the lack of political will, budget cuts, and lack of public awareness. However, the sum of lack of political will and poor decision-making amounts 35% of the responses.

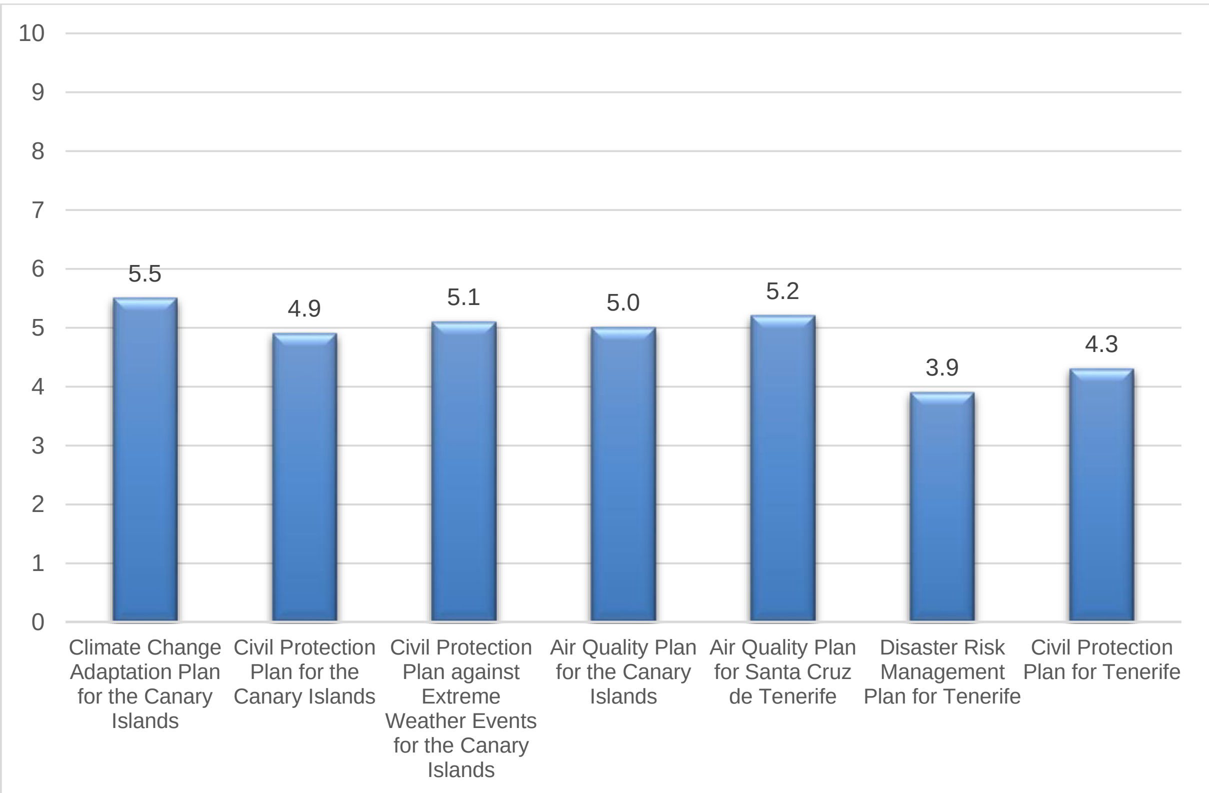
Figure 12. Stakeholders' opinions on the responsibility of the current situation



Source: own elaboration based on the questionnaire.

Apart from the divergences presented above (focused on the negative effects of the climatic and air pollution episodes), the most relevant different opinions have been revealed in the policy-making arena (regarding the policies reviewed in section 2.5). Generally speaking, the assessments given by the stakeholders to the existing policies, as useful policies for adaptation to climate change, are rather low (Fig. 13).

Figure 13. How good are current policies to adapt Tenerife to climate change?



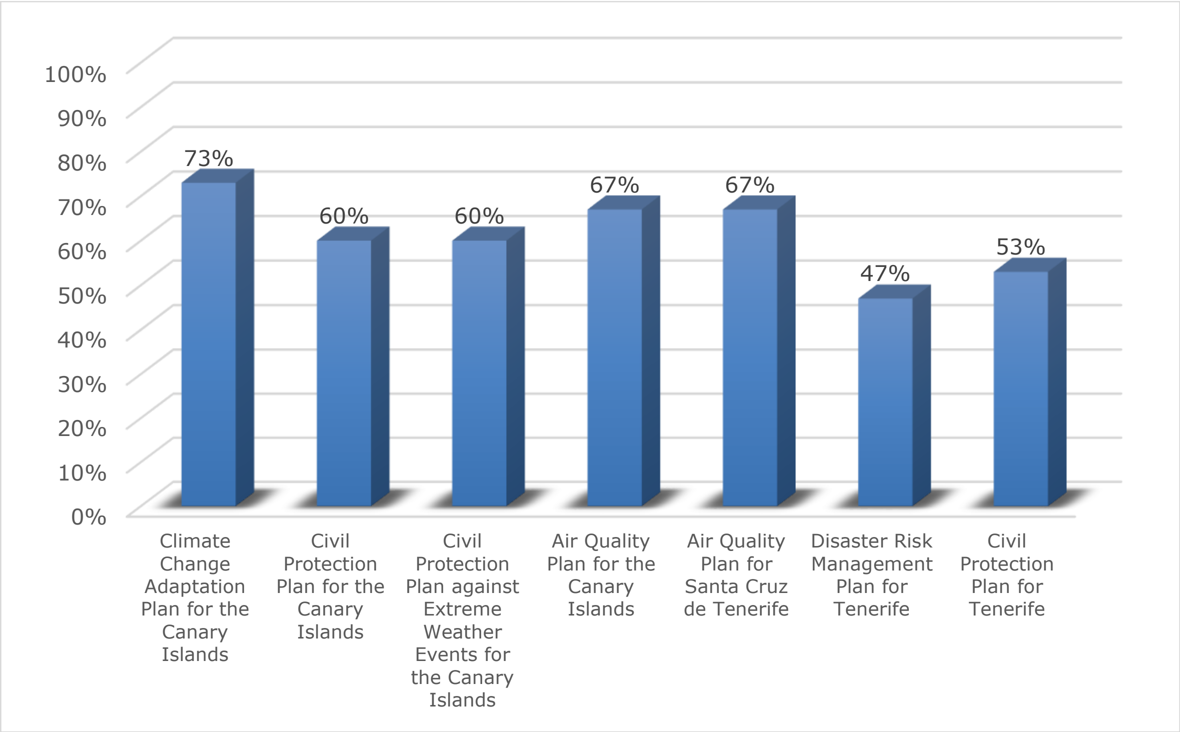
Source: own elaboration based on the questionnaire.

There are two core opinions on the existing policies: a) they are enough, and b) they are not enough to deal with heatwaves, Saharan dust events, and air pollution. In the first group of stakeholder are comprised of the *Department for the Environment and Landscape of the Council of Tenerife* (who declared that the existing policies are more than enough if implemented and upgraded when necessary), the *local trade union* (who mentioned that the current policies are good tools, although ignored), and one national trade union *UGT* (who declared that they are enough although they should have been developed in a more participatory way).

Meanwhile, the second group is much larger. For example, the correspondent for the *Department of Geography of the University of La Laguna* considers the Canary Islands adaptation and civil protection plans as no longer useful; the same was argued by the expert of the *Teide National Park*; the representative for the *Department of Physics of the University of La Laguna* suggested that the adaptation plan is not valid since global climatic models were used instead of specific climatic models for the Canary Islands; the representative for the *Institute of Tropical Diseases and Public Health of University of La Laguna* claimed that these policies do not cover all climatic hazards; the representative for the *Department for Pollution Prevention of the Government of the Canary Islands* suggests that they are not enough since not all them have been passed into law; it has also been said that current policies pursue other goals and scopes rather than adaptation to climate change (*Department for Civil Protection of the Council of Tenerife*); other actor mentioned that they are simply not enough to deal with climate change (*local environmental NGO*); lastly, an academic mentioned that these plans are disperse and unnecessarily overlapped (*United Nations Office for Disaster Risk Reduction*).

And last but not least, the lack of awareness among the stakeholders on the existing policies can also be considered relatively high, as seen in Fig. 14. The policies developed by the Government of the Canary Islands seem to be more well-known than the ones developed by the Council of Tenerife. Thus, the most well-known policy is the one concerning climate change adaptation for the Canary Islands: 73% of the stakeholder declared to have knowledge of this plan. Meanwhile, the Disaster Risk Management Plan for Tenerife is rather unknown (only 47% of respondents declared to be aware of it). This might indicate the lack of general awareness of current climate change adaptation-related policies.

Figure 14. Percentage of stakeholders aware of existing policies



Source: own elaboration based on the questionnaire.

4.1.4 Uncertainties detected

According to Funtowicz and Ravetz (1990) there are up to three different sort of uncertainties in the scientific analyses: technical, methodological, and epistemological. Technical uncertainty concerns inexactness and can be managed by means of error bars, meanwhile methodological regards unreliability and can be dealt with confidence intervals. Both of these uncertainties might in any case be managed through calculus and pure scientific approaches. However, epistemological uncertainties are rather connected to the border with scientific ignorance; that is, the uncertainty is beyond any calculus and scientific knowledge. These three kind of uncertainties have been identified in the institutional analysis implemented here:

— **Technical uncertainties**: refers to either inexistent or unpublished epidemiological follow-up studies/data on heatwave-related morbidity and mortality. Most of the stakeholders complain about the lack information on this issue, even though it is known to be collected. Thus, morbi-mortality could be indirectly estimated, although publishing existing data would reduce the uncertainties.

— **Methodological uncertainties**: these ones concern the policies reviewed in section 2.5. As seen, most of the stakeholders who have knowledge of the existing policies declared that they are neither reliable nor enough to deal with the issue under analysis. Therefore, the outcomes and proposals of these policies might not be trustworthy.

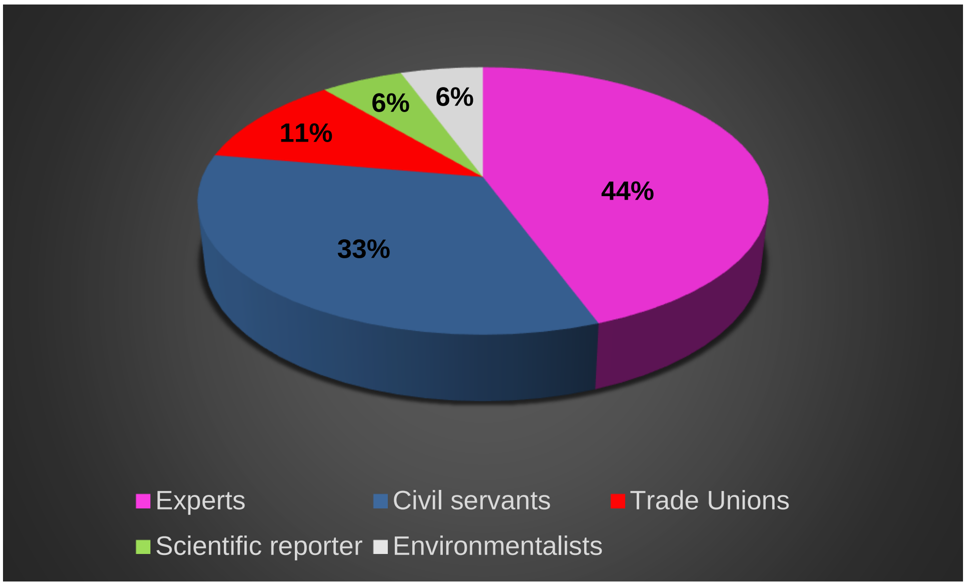
— **Epistemological uncertainties**: they were pointed out by both academics and institutional experts in climate change. Three high uncertainties were mentioned:

- The potential expected impacts of climate change in the Canary Islands are currently unknown, since the specific micro-climates of the Islands make global climatic models, usually applied elsewhere, unreliable; therefore, the direction of climate change impacts (either positive or negative) is currently not fully known.
- As a consequence of the previous uncertainties, the evolution of heatwaves and Saharan dust events are said to be not fully understood either.
- The potential combined negative effects of heatwaves, Saharan dust events, and air pollution have also been said to be fuzzy.

4.2 Step II: A focus group to frame climate policy in Tenerife

Eighteen people were invited to attend the focus group. The general profiles of those who attended the focus group are presented in Fig. 15. As seen, most of them were experts and civil servants. The latter group, representing the Government of the Canary Islands, the Council of Tenerife, and the Council of Gran Canaria.

Figure 15. Group of stakeholders and their weight in the total number of participants



Source: own elaboration based on the second step.

The participants were split up into two groups, in order to keep the same proportion of profiles per group as well as a certain degree of plurality. The division has been made as presented below in Table 18. As seen in Annex II, the focus group had three tasks: the two first tasks were developed in groups, meanwhile the last task was implemented altogether. Initially, the potential impacts of heatwaves, Saharan dust events, air pollution and their potential interrelations were discussed. Secondly, the stakeholders talked about potential actions that could be implemented. Lastly, an open discussion on the steps forward was carried out.

Table 18. Participants in the focus group.

Group 1		Group 2	
Participant	**Institution**	**Participant**	**Institution**
Expert in resilience	University of La Laguna	Expert in climate modelling	University of La Laguna
Expert in vector-borne diseases	University of La Laguna	Expert in vector-borne diseases	University of La Laguna
Department for Environmental Health	Government of the Canary Islands	Expert in ecology	University of La Laguna
Department for the Environment	Council of Tenerife	PhD student in resilience	University of La Laguna
Climate Action Group	Council of Gran Canaria	Deputy Minister's Office of the Environment	Government of the Canary Islands
Expert in air quality	Izaña Atmospheric Research Centre ([1])	Department for Epidemiology	Government of the Canary Islands
Expert in renewable energy	Research and Development Agency ([1])	Civil Protection Office	Council of Tenerife
Business group	Chamber of Commerce ([1])	Trade Union	Local trade union
Trade Union	National trade union ([1])	Scientific reporter	Institute of Volcanology
Environmentalists	Local NGO ([1])	Expert in climate and meteorology	Izaña Atmospheric Research Centre ([1])

([1]) The groups highlighted in italics could not attend the focus group session.

4.2.1 Framing the issue altogether

Each group talked about heatwaves, Saharan dust intrusion, air pollution events, their potential correlations as well as their impacts on the environment and population health. Afterwards, a representative of each group presented their conclusions. These conclusions were the following:

Increasing temperatures

There was a consensus on the idea that the Canary Islands are registering an increase in the average temperatures as a consequence of climate change. The stakeholders also agreed that this increasing temperatures are becoming more relevant in mountainous areas.

What is a heatwave?

The stakeholders complain about the lack of a proper definition of what a heatwave means in the Canary Islands. They considered this definition as a relevant first step to begin with policy actions regarding protection against potential increasing heatwave events.

Heatwaves and environmental impacts

According to the stakeholders, the combination of temperatures above 30°C, relative humidity below 30%, and wind speed above 30 km/h is highly correlated with forest fires. Furthermore, it was also said that not only forest fires but also heatwaves might produce changes in the distribution of tree species.

Correlations between heatwaves and Saharan dust intrusion

According to the stakeholders, this correlation cannot be guaranteed. However, it could be possible that a certain overlapping of both events might occur in summer time. What is sure, according to the stakeholders, is that Saharan dust intrusion events are correlated with the arrival of pathogenic to the Islands. It was also said that increasing hospital admissions as a consequence of the exposure to Saharan dust is well known in the Islands.

Correlations between heatwaves and air pollution

Santa Cruz de Tenerife presents a series of specific characteristics in terms of wind patterns and orography that usually lead to air pollution concentrations in the city, as a consequence of both local sources of emissions as well as some continental pollutant arrivals. However, according to the stakeholders, heatwaves and air pollution are independent uncorrelated events in Tenerife. Several correlations between air pollution and Saharan dust events were also mentioned.

One recommendation given by the stakeholders

The stakeholders agreed on the necessity of dividing the island into zones in order to have a clearer vision of climate risks as well as air pollution concentration and exposure.

4.2.2 Proposals for policy actions and assessment criteria

One of the tasks planned for this focus group session was the proposal of adaptation policy actions. The discussion among the experts and stakeholders came up with the next list of proposals consisting of «actions of structure» and «actions of implementation». The first group of actions (of structure) is comprised of:

— **Action 1**. Create an administrative structure to be the backbone of mainstreaming climate change policy across both public and private institutions: a Climate Change Agency like this used to exists some years ago in the Canary Islands. It was created the 24th of April 2009 by means of a regional law. The aim of the Agency was the promotion, encouragement, orientation and coordination of policies, initiatives and measures to reach sustainable development as well as the mitigation and adaptation to climate change. For more details BOC (2009) can be consulted. The 25th of June 2012 the Government of the Canary Islands launched a regional law intended to adopt measures to reduce public administrations expenditure in order to respond to the financial crisis. The preface of the law indicated that budget cuts were required so as to «guarantee public expenditure sustainability» within an economic crisis that obliged the public administration to fulfil the objectives of budgetary stability (BOC, 2012).

— **Action 2**. Create a permanent technical Forum or Committee on climate change issues: it should be composed of existing local experts on climate change that may play a role in climate change governance through the administrative structure mentioned in action 1.

— **Action 3**. Create a permanent social Forum or Committee on climate change issues: it should be formed by local stakeholders interested in climate chance policy. They may also play a role in climate change governance through the administrative structure mentioned in action 1.

Regarding the «actions of implementation», it was proposed the next:

— **Action 1.** Carry out an integrated state-of-the-art regarding climate change issues.

— **Action 2.** Upgrade the Canary Islands' Climate Change Strategy.

— **Action 3.** Carry out information and communication campaigns on climate change mitigation and adaptation.

The stakeholders were also asked to propose a list of criteria that might be of use to build scenarios for resilience. They were the next:

— **Environmental criteria:**

- CO_2 emissions.
- PM_{10} concentration.
- $PM_{2.5}$ concentration.
- SO_2 concentration.
- NO_2 concentration.
- Energy consumption.
- Water consumption.

— **Social criteria:**

- Premature death.
- Hospital admission for respiratory diseases.
- Hospital admission for cardiovascular diseases.
- Energy poverty.
- Green area availability.

— **Economic criteria:**

- Health costs.

- Economic activity.
- Employment.
- Investment costs.
- Maintenance costs.
- Energy costs.

4.3 Step II: Citizen engagement

Three focus groups were carried out in the island: the first in the Municipality of La Laguna, the second in the Municipality of La Orotava, and the third in the Municipality of Icod de los Vinos (see Fig. 16).

La Laguna belongs to the metropolitan area of Tenerife. It is the second most populated municipality with more than 152,000 inhabitants (ISTAC, 2016d). La Laguna belongs to the signatories of the Covenant of Mayors (Covenant of Mayors, 2016). 15 people attended the open call made two months in advance. The educational level of the attendees was high; in fact, all of them had at least a University degree. Their concern was systemic, that is, adaptation to climate change was expanded to a problem of island resilience, where energy, water and food production independency were considered relevant to increase islanders resilience against external shocks.

The second focus group was carried out in the Municipality of La Orotava. Its population is around 41,000 inhabitants (ISTAC, 2016d). 18 people attended this session. In this case, both high educated and lay people shared their opinions regarding climate change adaptation, although those with high educational level were the majority. Again, the problem was thought as systemic and the broader view of resilience came out during the session once again. Increasing energy, water, and food production rates might reduce the island vulnerability against international or global shocks. However, specific actions were proposed so as to adapt the island to heatwaves, such as increasing levels of green infrastructure in urban areas.

The last focus group session took place in Icod de los Vinos, which is a more rural area. This municipality has almost 23,000 inhabitants. 10 people attended the open call. The main characteristic of this session were a) most of the attendees were lay people, and b) the shorter number of attendees was used to go into details regarding concrete adaptation actions.

Figure 16. Location of focus group sessions

Source: own elaboration based on the second step.

4.3.1 Framing the issue altogether

Mitigation is still perceived as a key climate policy

Even though the Canary Islands are responsible for only 0.03% of global greenhouse gases emissions ([8]), the attendees of all sessions consider relevant to reduce greenhouse gases emissions in Tenerife and the Canary Islands. They mentioned that the more emissions are released to the atmosphere, the more adaptation would be required. Furthermore, they are also aware of the fact that reducing greenhouse gases emissions would imply ancillary benefits in terms of air quality, less road congestion and general environmental and health benefits.

Environmental governance

The attendees have also highlighted the lack of political will when implementing environmental protection policies. It was mentioned that the Climate Change Agency of the Canary Island was shutdown in 2012 due to climate change policy in particular and environmental protection in general are not a local governmental priority.

Water, agriculture and local food production is a key issue

As mentioned above, the scarcity of water, the high reliance on external fossil fuel and the low local food production were a recurrent concern. The attendees saw the problem much broader than a mere question of adaptation to climate change; instead, they believe that it is a matter of increasing the resilience against external shocks. Thus, reducing external energy and food production dependency is perceived as a key policy issue.

4.3.2 Proposals for policy actions

Even though these three focus groups sessions produced more results in terms of policy actions (that will be deeply used in step III), a good summary of the policy proposals are the next:

— **Action 1.** Create an administrative structure to be the backbone of mainstreaming climate change policy across both public and private institutions: again, this action coincide with the one proposed by academics and institutional experts in the first focus group session.

— **Action 2.** Carry out an integrated state-of-the-art regarding climate change issues. According to the attendees, a diagnosis of the current situation and the expected climate change impacts for the future is still needed for the island.

— **Action 3.** Improving environmental governance: a more democratic and participatory environmental decision-making is needed. Citizens interested in climate change policy should be considered from the beginning of climate governance so as to have a more robust decision. This action may also coincide with the action 3 (actions of structure) proposed by academics and experts in the first focus group session.

— **Action 4.** Carry out information and communication campaigns on climate change mitigation and adaptation. Prevention campaigns are important to implement self-protection measures when an extreme climatic event may happen in the island.

([8]) Global emission data for 2005 from the Canary Islands (ACDSCC, 2008) and the World Resource Institute (Herzog, 2009) were used to calculate this rate.

5 Discussion

5.1 Some policy lessons

Even though this project still need further research (see section 5.2), several policy lessons might be assumed. As seen in section 4.2.2, a Climate Change Agency used to exist in the Canary Islands since 2009 until it was shutdown in 2012 for budgetary reasons. According to what was said during the focus groups, the lack of institutions in charge of climate change policy prevents the proposal and implementation of policy options and specific actions to increase climatic resilience. As a consequence, local academics, institutional experts and other stakeholders, as well as the citizens addressed in the last three focus group sessions, indicated that the lack of institutions is a key drawback to move forward in climate policy (see section 4.2 and 4.3). This claim coincides, therefore, with the recommendations given by the European Environment Agency on what good governance is about, i.e. to have available stable institutional structures able to work regardless electoral cycles or political changes (EEA, 2012b). Consequently, ***it might be reasonable to create an Agency, or an institutional structure, exclusively in charge of climate change policy***, in order to guarantee coordination among public and private institutions and mainstreaming climate policy across local administrations.

Secondly, as seen in section 4.1.4 there are uncertainties regarding climate modelling and extreme weather events prevention. As a consequence of the existing micro-climates in the Island, global climatic models might not be reliable to predict extreme weather events, such as heatwaves or Saharan dust events, as well as their trend in the future. It was also mentioned the need for high-resolution climatic models so as to have proper adaptation plans (see Table 17). In fact, the current Climate Change Adaptation Plan considers the need for investment in Research & Development tools to predict what areas of Tenerife might be more affected by heatwaves, Saharan dust events or air pollution (Martínez, 2010). Consequently, ***it might be reasonable to dedicate more resources to R&D in order to have better early warning systems for extreme weather events***, in order to protect local population and the island environment from those extreme events.

Third, as mentioned in section 4.1.2, disaster risk management plan including climate change risks is needed in Tenerife, since the existing one does not cope with climate change, but other natural disasters (see section 2.5). It was also mentioned during in-depth interviews that risk reduction policies should substitute civil protection ones, as well as the need for specific action plans for adaptation to climate change (see section 4.1.2). Furthermore, in section 2.5 can be seen that existing policies regarding climate change are diverse but disperse, i.e. they are split up into regional and local level, whereas several policies cope with climate change indirectly. As a consequence, ***it might be reasonable to develop a climate change risk management plan to island levels***, since, as mentioned throughout the report, micro-climates are the main characteristic of Tenerife.

According to what was discussed during the focus groups sessions developed with local citizens, most of the measures to protect people and the environment against heatwaves and Saharan dust events (Tables 9, 10, and 11; see also Gobierno de Canarias, 2006) were mentioned by local citizens as good self-protection measures against extreme weather events. Consequently, ***it might be reasonable to reuse or consider the measures proposed in the Civil Protection against Extreme Weather Events Plan as potential adaptation actions***.

Although local citizens mentioned that the existing self-protection measures against extreme weather events are useful, they were neither aware of their existence, nor the policies where they are written. However, this lack of awareness is not constrained to citizens and lay people: as declared by the academics, institutional experts and other stakeholders' interviewed, a certain percentage of them declared not to be aware of the existing policies on the issue (see section 4.1.3). Thus, more than half of the stakeholders interviewed declared not to be aware of the current Disaster Risk Management Plan for Tenerife; almost half of them declared to be unaware of the existing Civil Protection Plan for Tenerife; where as 40% of them do neither know the existence of the Civil Protection Plan for the Canary Islands, nor the Civil Protection Plan against Extreme Weather Events for the Canary Islands. Therefore, ***it might be reasonable to carry out information campaigns on the existence of those plans in the meantime further actions are undertaken.***

5.2 The way forward

Step III of this research project will be devoted to build scenarios for resilience in Tenerife. As seen in section 4.3, local citizens are not only concerned about adaptation to climate change, but how to be more resilient against external shocks, including extreme weather events as a consequence of climate change. Thus, those scenarios, still to be built, will propose paths that Tenerife may walk through from current times to 2040 in order to increase its resilience. These scenarios would concentrate on energy, agriculture, and food dependency, as well as other driving forces that might affect Tenerife's resilience.

6 Conclusions

The expected impacts of heatwaves, Saharan dust events, and air pollution in Tenerife has been reviewed and presented. Potential negative impacts on human health and local ecosystems can be foreseen, indicating that the Canary Islands and, therefore, Tenerife is highly vulnerable to climate change (López et al., 2016). Concretely, heatwaves have been shown to be increasing in frequency and intensity during the last decades in the Canary Islands.

There are currently a certain number of policies at both the Canary Islands scale and at Tenerife scale that, either directly or indirectly, might deal with the multiple hazards analysed here. However, most of these policies have neither been specifically developed to increase the resilience against heatwaves, Saharan dust events, and climate change, nor to deal with their potential interactions. Therefore, their possible capability need to be explored along with other potential adaptation actions.

In this report a participatory integrated assessment has been proposed to approach climate change risks in small islands. The approach applied here is based on the combination of three methodologies a) institutional analysis (press review and local law), b) participatory techniques (in-depth interviews, questionnaires, and focus groups), and c) scenario building (this last step still to be carried out). These methodologies were used to frame climate change risks in Tenerife, as well as to propose, along with local stakeholders, potential paths for a more resilient island, including its adaptation to increasing heatwaves, Saharan dust events, and air pollution. Furthermore, the stakeholders were also able to propose environmental, social and economic criteria that could be used for the next step, i.e. the exploration of scenarios for resilience and adaptation policy options.

One of the findings of the analysis is that there is a lack of institutions in charge of climate change issues. According to most of the participants, the Islands need an institutional structure in charge of mainstreaming climate change policy into private and public institutions. A second finding indicates that an integrated climate change risk management plan is also needed as well as the investment in high-resolution climatic models. Third, it has also been highlighted that the existing civil protection plan against extreme weather events for the Canary Islands includes interesting self-protection measures against heatwaves and Saharan dust events, as declared by local citizens during the focus group sessions. However, this plan is rather unknown by local residents. Thus, information campaigns should be carried out to give more visibility to these existing self-protection measures.

Step III of this research project will be devoted to build scenarios for resilience in Tenerife. As will be presented, local citizens are not only concerned about adaptation to climate change, but also about how to be more resilient against external shocks, including extreme weather events as a consequence of climate change. Thus, those scenarios, still to be built, will propose paths that Tenerife may walk through from current times to 2040. These scenarios would concentrate on energy, agriculture, and food dependency, as well as other driving forces that might affect Tenerife’s resilience.

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Annexes

Annex 1. On-line questionnaire

- What is the scope of the organism you work for? Local, insular, regional or national? (Respond only if appropriate).
- Heatwaves are becoming frequent and they are related to air pollution concentrations. Is this a current problem in Tenerife?
- Is there official figures regarding the impacts on human health? Is there an epidemiological follow-up analysis?
- Is there any specific plan either in Tenerife or in the Canary Islands to deal with these problems? Could you qualify the next policies from 0 to 10?
- In case of considering these plans as incomplete, what alternatives or complementary measures would you propose?
- What are the main obstacles to the implementation of these plans or measures?
- What criteria do you think would be needed for the assessment of alternative policy packages?
- What expert, organism or stakeholder should be contacted to be involved in the participatory process? Could you provide his/her contact (e-mail)?

Annex 2. Focus group Agenda with experts and stakeholders

It took place in the Mencey Hotel of Santa Cruz de Tenerife on the 5th of July. The Agenda followed the next structure:

9:00-9:15. Stakeholders presentation.

9:15-9:30. Presentation of the project.

9:30-10:15. Impacts of heatwaves, Saharan dust intrusion, and air pollution at the local level.

10:15-11:15. Existing policies and proposal of new policy options.

11:30-13:00. Discussion of policy options.

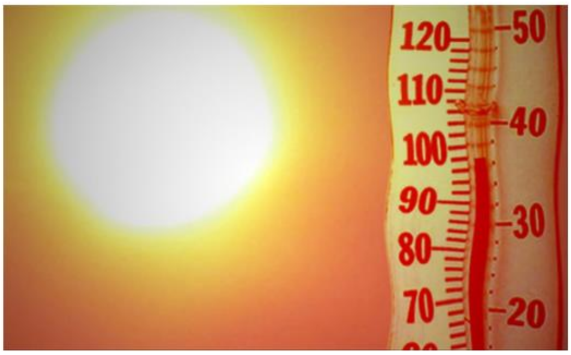
13:00. Farewell

Annex 3. News in 2040

El Cotidiano de Tenerife

El cambio climático, detrás de las crecientes olas de calor y la calima

Los científicos afirman que las olas de calor de más de 45°C serán cada vez más frecuentes en Canarias



Los expertos en cambio climático que trabajan para el Gobierno de Canarias, han confirmado a este periódico que las Islas se enfrentan a una creciente llegada de olas de calor con temperaturas superiores a los 45°C. Del mismo modo, los expertos afirman que el tiempo sahariano será cada vez más frecuente y su duración más larga. Según los expertos, debían haberse tomado medidas hace más de veinte años. El cambio climático es ya un problema ambiental irreversible.

El Cotidiano de Tenerife

Más de 100 personas ingresan en los Hospitales por golpe de calor

Un total de 117 personas han tenido que ser ingresadas durante los meses de julio y agosto por golpe de calor

Los hospitales se encuentran actualmente colapsados ante la llegada de más de cien personas con problemas relacionados con el calor de estos días. La mayor parte de los afectados son ancianos y personas con enfermedades crónicas. Los gestores de ambos hospitales afirman no saber cómo gestionar el problema, dado que los recursos destinados a la sanidad pública no han hecho sino reducirse desde la crisis financiera producida hace dos décadas.

El Cotidiano de Tenerife

Los efectos de la ola de calor y la calima colapsan todos los Hospitales

Los trabajadores aseguran que no se trata de un pico puntual, sino de una situación cada vez más frecuente

Los sindicatos afirman que la situación es totalmente insostenible para los pacientes y los trabajadores de los Hospitales. La escasez de espacio y las altas temperaturas hacen imposible un tratamiento adecuado de los pacientes, especialmente de los más ancianos. Los pacientes se quejan de la falta de planificación ante los efectos del calor y la calima. Uno de los pacientes afectados, de 93 años, afirma que ha podido notar en su larga vida cómo las olas de calor y la calima "han ido a más.

El Cotidiano de Tenerife

El 70% de la población tinerfeña respira aire contaminado

Las centrales térmicas, la refinería, la actividad portuaria y el tráfico rodado son los principales responsables

Algo más de dos de cada tres personas han respirado aire contaminado en el último año en Tenerife. Según un estudio elaborado por el Gobierno de Canarias, se ha producido un aumento generalizado de los niveles de contaminación en las últimas décadas en la isla. Los niveles de partículas en suspensión, el dióxido de nitrógeno y el dióxido de azufre son los responsables del problema. Los hospitales de la isla han registrado una creciente demanda de personas con problemas respiratorios derivados de la contaminación.

El Cotidiano de Tenerife

La producción de vino en riesgo por el cambio climático

Los viticultores se enfrentan a pérdidas de un 60% en la producción de vino a causa del creciente calor

Los productores de vino han venido registrando pérdidas anuales en torno a un 60% desde 2015. Culpan a las crecientes olas de calor y la llegada de calima. Ambos fenómenos traen a Canarias una maduración no natural de la uva y enfermedades como el mildiu. Las pérdidas en la producción se están reflejando en los precios del vino. Mientras en 2015 un litro de vino se compraba a 6 euros, hoy, en 2025, un litro de calidades similares se compra a unos 20 euros. La demanda de vino ha caído de forma drástica.

El Cotidiano de Tenerife

Tenerife se queda sin papas por primera vez en la historia

El creciente calor es el responsable de que se haya perdido toda la producción de papa en la Isla

Por primera vez desde que existen registros de producción, Tenerife tendrá que satisfacer toda su demanda interna de papa a través de la importación. El Gobierno de Canarias, el Cabildo de Tenerife, los Ayuntamientos y los agricultores no dan crédito. La reducción en la disponibilidad de agua, la llegada de enfermedades por la calima y el fuerte calor han dejado a la isla sin capacidad de producir papa para el autoconsumo. Muchos pequeños agricultores se plantean dejar la actividad.

Annex 4. Focus groups with citizens

Figure 17. First session in the Ateneo of La Laguna (31/10/2016)

Figure 18. Second session in the Liceo de Taoro of La Orotava (02/11/2016)

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