HARVARD
T.H. CHAN
SCHOOL OF PUBLIC HEALTH

International Sustainable Tourism Initiative (ISTI)

Research project:

Tourism and Environmental Health in a Changing Climate

Implementation in Tozeur and Djerba, Tunisia

July 2017-December 2018

Funded by GIZ, The German Development Cooperation Agency

Final Report Authors:
Megan Epler Wood, Sofia Fotiadou , Zain Jarrar and Misbath Daouda

In cooperation with

HARVARD Kennedy School
BELFER CENTER
FOR SCIENCE AND INTERNATIONAL AFFAIRS
Environment and Natural Resources Program

Project team

Principal Investigators:
Dr. John D. Spengler - Harvard Chan School of Public Health (HSPH)
Dr.Henry Lee - Harvard Kennedy School (HKS), Belfer Center for Science & International Affairs

Lead Researcher:
Megan Epler Wood - ISTI Program Director

Researchers:
Sofia Fotiadou (Research Manager ISTI)
Misbath Daouda (Research assistant HSPH)
Zain Jarrar (Graduate Researcher HKS)

Local collaborators/ experts:
Dr. Nabil Gasmi (CGMED, University of Sousse),
Dr. Olfa Helali (ISET of Djerba) and Farhat Bentanfous (Djerba)

Preface & Acknowledgements

The International Sustainable Tourism Initiative (ISTI) is a program in the Department of Environmental Health at the T.H. Chan School of Public Health at Harvard University. ISTI has developed an indicators framework for sustainable tourism, the *ISTI Framework*, to help destinations measure tourism's demand for resources and climate change-related impacts, as well as monitor efforts towards transitioning to a greener economy. The ISTI Framework aims to provide local authorities with the data required to measure the full cost of tourism growth and help align measurements in tourism's economic sector with international commitments under the Paris Agreement and the Sustainable Development Goals. This report presents the results of the pilot implementation of the ISTI Framework in Djerba and Tozeur, Tunisia, as part of a research project financed by the German Agency for International Cooperation (GIZ). The pilot implementation of the ISTI Framework entailed a significant effort in local data collection. The Higher Institutes of Technological Studies (ISET – *Institut Supérieur des Etudes Technologiques*) in Djerba and Tozeur contributed significantly to this effort and we would like to specifically thank Djerba's ISET director, Nèjib Bouabidi, and Tozeur's ISET director, Jeddi Othman, for their support and contribution.

Executive Summary

A holistic framework for measuring the full cost of tourism growth was researched and formulated by the International Sustainable Tourism Initiative (ISTI) at the Harvard T.H. Chan School of Public Health to offer a science-based system for tourism destinations in order to measure resource use and climate change-related data at the destination level, as well as monitor transition of their tourism sector to the green economy. This framework, called the *ISTI Framework*, was based on extensive research related to the interactions between tourism, the environment, and climate change, and draws from global data frameworks that stress sustainable resource and carbon management at the local authority level. The German Agency for International Cooperation (GIZ) funded a test of the ISTI Framework in Tunisia in the destinations of Tozeur and Djerba during an 18-month project launched in July 2017.

In effect, the ISTI Framework was being tested to play two distinct roles 1) to provide a science-based set of measures for national Nationally Determined Contribution (NDC) reporting for the Paris Agreement, and 2) to provide a set of local, precise measures of the unaccounted for demands tourism growth places on local resources and utilities, including water, wastewater, energy, solid waste, and land-use to guide informed decision making by local leaders who seek to meet the Sustainable Development Goals (SDG) for their regions and the needs of local citizens.

Data acquired in Djerba were more robust than in Tozeur, hence research results were largely based on Djerba. The research demonstrated that 1) without further monitoring and management at the destination level, tourism will play an increasingly energy- and resource-intensive role, which will not be consistent with Tunisia's NDC goals under the Paris Agreement, and 2) tourism has many unmonitored and unaccounted for impacts on local destinations, which cannot be overseen by municipal leaders without data to guide the development of sustainable, efficient economies and to meet the Sustainable Development Goals.

Research on the intensity of tourism demand for energy at the destination level, and the entailed greenhouse gas (GhG) emissions, was one of the primary goals of the research program in Tunisia. It was found that the per tourist night carbon emissions in Djerba were over 3 times higher than the per capita emissions in Tunisia as a whole. As growth strategies are being set out by the national government, it will be imperative to review the GhG emissions per tourist to ensure that Djerba remains on its decarbonisation path as part of Tunisia's committed goals for the Paris Agreement (i.e. 41% unconditioned and conditioned reduction in carbon intensity by 2030).

Water scarcity is a reality throughout Tunisia, a fact of great importance for the future of tourism in Djerba and Tozeur, which are part of the most arid region, Medinine. In 2017, tourism was responsible for 25% of total water consumption in Djerba, with the per tourist consumption rate notably higher than what has been reported for other Mediterranean destinations.

Tourism contributed approximately 25% of the municipal solid waste generated on Djerba Island in 2017, without a managed landfill to handle waste. A 'temporary' bulking site was created in 2015 with the purpose of serving three municipalities until a permanent solution is found, posing a significant health hazard. It is therefore abundantly clear that measuring and monitoring tourism's solid waste management crisis has important implications for Djerba Island.

In 2017, tourism was responsible for 57% of wastewater production on Djerba Island. While wastewater from tourism facilities is treated 100%, local residential area treatment rates are much lower. Tourism workers now and in the future on Djerba Island will lack wastewater treatment. Solutions for the areas outside the tourism zone would lower per person treatment costs on the island year-round, something Djerba's primary municipality, Houmt Souk, would support in order to both meet SDG goals and protect Djerba's famed sea waters – the country's primary tourism attraction.

By 2015, 9.6% of Djerba's coastline was urbanized for tourism development causing a receding coastline. While the Agency for the Protection of Coastal Development (APAL) monitors the impact of climate change on

the coast, this is costly, and more public-private cooperation is needed to protect the coastline for tourism and the local population.

Alongside testing the ISTI Framework, a policy analysis was undertaken in 2018 by a Harvard Kennedy School masters degree graduate in Middle Eastern studies to determine how the growth of tourism can be understood as part of the nation's larger policy goals to preserve the environment and lower greenhouse gas emissions. Tunisia's new constitution has been called one of the most progressive in the world in terms of disabled rights, gender equality, advanced healthcare policies, and climate change commitment. The constitution is one of only three in the world that recognizes "the necessity of contributing to the preservation of a healthy environment that guarantees the sustainability of our natural resources," and Article 45 necessitates that the government ensures the right "to a healthy and balanced environment" and to "provide the necessary means to eradicate environmental pollution."

Tunisia's tourism policy has traditionally been led by the National Office of Tunisia Tourism (ONTT), which is the body that manages tourism demand under the Ministry of Tourism and Handicrafts. The ONTT does not have an environmental mandate per se, and therefore lacks the capacity to manage science-based data on the impacts of tourism growth. At the national level the Ministry of Environment oversees the management of science-based data on the different economic sectors, but there are no formal agreements relating to the management of the tourism sector between the Ministry of Environment and the Ministry of Tourism and Handicrafts or the ONTT.

Two final workshops were held on Djerba Island on November 15 and 16, 2018, to review the data and policy results of the research program among a range of policy makers, business people, civil society members, and the research community. The first workshop, on November 15, was held with representatives of the research community, primarily instructors with the Djerba Institut Supérieur des Etudes Technologiques (ISET). The second, on November 16, was over 50% policy makers from Djerba, Tozeur, and the national government. Business was represented via federation leaders and prominent business people. Civil society was represented by respected leaders of local NGOs. Representatives from Djerba discussed the formation of an on-going data analysis program via the fully approved Conseil de Tourisme, which oversees the region and has the authority to receive data directly from utilities. In Tozeur, the newly-elected female mayor suggested that the municipality is best suited for creating a data unit to ensure that key resources, such as water, are carefully monitored as tourism grows. The Deputy Director of the national Ministry of Environment, and chief liaison for climate change reporting for Tunisia, called for a replication of the ISTI Framework via ISET in 2022 to monitor the impacts of tourism growth.

Together, government and its representatives are seeking to work with business, via their federations, and with civil society in Djerba and Tozeur to replicate the ISTI Framework for their planning processes in future. The overall goals of the project – to measure both tourism's demand for resources and climate change-related impacts and inform local governments – have been met. The final workshops on Djerba Island confirmed that policy makers, business people, and local academic representatives agree that research and data centers would offer beneficial and important information to transition to a more efficient, sustainable tourism economy.

Introduction

Tourism and International Commitments for Sustainable Development and Climate Change Mitigation and Adaptation

The Harvard T.H. Chan School of Public Health founded the *International Sustainable Tourism Initiative (ISTI)* in 2014 to undertake global research on managing tourism using science-based approaches and indicators as related to human and environmental health. At the time of ISTI's founding, peer-reviewed articles had already concluded that tourism's consumption of resources such as energy, water, land, and the resulting CO2 emissions, would roughly double by 2050 (Gössling et Peeters, 2015). Between 2009 and 2013, tourism's global carbon footprint (including direct and indirect energy needs) accounted for 8% of global greenhouse gas emissions with a 95% level of confidence (Lenzen et al., 2018). Global demand for tourism is outstripping the decarbonization of tourism operations and accelerating global carbon emissions. Neither responsible travel behaviour nor technological improvements have been able to offset the increase of tourism's carbon footprint (ibid).

Multi-year efforts to reach global consensus and establish international agreements among governments, civil society, and the corporate world were completed in 2015 to deal with the global challenges of sustainable development and human-induced climate change. The 2030 Agenda for Sustainable Development and its 17 Sustainable Development Goals (SDGs) that foster peace and prosperity for people and the planet, and the 21st Conference of Parties (COP21) to the United Nations Framework Convention on Climate Change (UNFCCC) held in Paris, reached unprecedented levels of agreement, signed by more than 190 member states. Tourism is a resource-intensive industry and both of these agreements call for absolute reductions in resource use. A number of SDGs address the tourism sector directly such as SDG 8, 12, 14, or indirectly by means of setting goals on reducing consumption and conserving the types of resources that tourism depends on. The signing of the Paris Agreement was an historic effort to set benchmarks for emissions, establish effective reporting systems, and accelerate innovation in the effort to move towards more carbon-efficient economies — making it highly relevant to the tourism sector (Scott, Hall & Gössling, 2016). The Paris Agreement has mechanisms that require all country-parties to the agreement to report on climate change mitigation and adaptation action through nationally coordinated systems, including the Nationally Determined Contribution (NDC) documentation. Parties to the UNFCCC submitted, well in advance of the COP21, their (intended) Nationally Determined Contribution (NDC) to climate change action in accordance with their national circumstances. Countries where tourism is a significant contributor to their economy will inevitably need to implement their NDC through policies and strategies that pertain to tourism's demand and consumption.

ISTI undertook internal research to review the extent to which countries considered the tourism sector in their Nationally Determined Contributions (NDCs) and found that among the 122 Parties to the UNFCCC where tourism is a contributor to the country's economy, 52 countries (43%) included tourism in their NDC, addressing the sector's vulnerability and/or contribution to climate change. Almost all of these Parties referred

to the vulnerability of the sector to climate change impacts (coastal erosion, flooding, landslides, level of resiliency of coastal and port infrastructure, etc.), and approximately half of them discussed relevant tourism sector-specific mitigation action, or economy-wide mitigation strategies that also pertain to tourism, as well as the importance of mitigation co-benefits resulting from adaptation strategies that involve the tourism sector.

During COP22's session on *Advancing Sustainable Tourism in a Changing Climate*, ISTI made the case that advanced monitoring of harmonized data on resource use and climate change-related impacts would reduce the environmental impacts of tourism and create solutions including awareness, efficiency and compliance at the local level. This recommendation was included into the final report for the session (10 YFP Sustainable Tourism Program, 2016).

The ISTI framework

A holistic framework for managing the full cost of tourism growth was researched and formulated by ISTI to offer a science-based system for tourism destinations that fosters the measurement of resource use and climate change-related data at the destination level and the monitoring of the local tourism sector's transition to the green economy. The framework aims to guide decision making on sustainable tourism management, which directly or indirectly contributes to nations' processes for Nationally Determined Contribution (NDC) implementation under the Paris Agreement, as well as their commitments to the Sustainable Development Goals (SDGs). The German Agency for International Cooperation (GIZ) funded a test of the ISTI Framework in Tunisia in the destinations of Tozeur and Djerba during an 18-month project launched in July 2017.

This framework was based on extensive research related to the interactions between tourism, the environment, and climate change, and draws from global data frameworks that stress sustainable resource and carbon management at the local authority level. Alongside this research three important documents were used as background for the definition of the framework's indicators:

- *Indicators of Sustainable Development for Tourism Destinations – A Guidebook* (UNWTO, 2004)
- *The Global Protocol for Community-Scale Greenhouse Gas Emission Inventories* (WRI, C40 Cities, ICLEI, 2014)
- Planning Guidelines for Sustainable Cities of the *Zofnass Program for Sustainable Infrastructure* (Pollalis, 2016)

The ISTI Framework includes a set of indicators, the majority of which are quantitative, to allow progress tracking and measurable outcomes. The framework consists of two sections; the first is for *measurement and benchmarking* and the second for *monitoring progress* towards more sustainable solutions. In fact, the second section consists of a set of strategies for transitioning to a greener economy that could be applicable to many

destinations and are expressed in the form of measurable indicators. Destinations applying the ISTI Framework need to first use the first section on *measurement* to create a data baseline that can guide decision making on the sustainability strategies that need to be adopted. These strategies can be sourced from, or be supplemented by, the strategies/indicators of the second section of the ISTI Framework. Although the strategies included in the second section of the ISTI Framework are not meant to be exhaustive, nor are they all applicable to all destinations as there is no solution that 'fits all,' these form a relatively comprehensive guide for decision and policy making at the destination level.

The pilot implementation of the ISTI Framework in Tunisia aimed to test the feasibility framework to serve as a tool to: 1) provide a science-based set of measures that can contribute to national NDC reporting, and 2) provide a set of local, precise measures of the unaccounted for demands tourism growth places on local resources and utilities, including water, wastewater, energy, solid waste, and land-use. Goal 1 is a national goal that responds to the need for national governments to monitor tourism's rising carbon footprint as part of their decarbonization commitments and the sector's areas of vulnerability to climate change impacts. Goal 2 is in response to the need for local authorities to appropriately gauge the costs of tourism on their budgets, non-renewable resources, tax payers, and local economy. Overall, Goal 2 aims to help local municipal governments plan for creating more efficient uses of local resources and transition to a more sustainable tourism economy while at the same time, implicitly or explicitly addressing many of the SDGs. To understand how these goals could best serve specific Tunisian needs, policy research was undertaken as part of the pilot initiative.

Tunisia's Political Environment and Tourism

In 2011, Tunisia was the launch point for the 'Arab Spring' revolutions. Since 2011, It is considered to be the only country in the Arab world that has successfully transitioned to an open and democratic system of governance (Salem, 2015). In 2014, Tunisia made steady progress in overcoming political deadlock by adopting a new constitution and holding both parliamentary and presidential elections. It also adopted many new laws that changed the governance structure in the country and redefined power relations between the central government and local authorities.

Tunisia's new constitution has been called one of the most progressive in the world for many of its aspects. It promotes disabled rights, gender equality, advanced healthcare policies, and climate change commitments. The constitution is only one of three countries in the world that recognizes "the necessity of contributing to the preservation of a healthy environment that guarantees the sustainability of our natural resources," and Article 45 necessitates that the government ensures the right "to a healthy and balanced environment" and to "provide the necessary means to eradicate environmental pollution." It is also unique in the Arab world for stressing equal citizenship for women. Under the new Tunisian constitution, gender equity is a clear and

explicit goal. This has resulted in women holding 30% of the National Assembly in 2017, a percentage that is higher than the world average of 21% (Mekki, 2014).

The country has also made legal strides toward decentralizing and giving more power to local authorities. One of the most notable laws is No. 2017 (April 26, 2018), which governs the organization of local power by creating a decentralized policy environment. This law essentially gives more freedom to local authorities to plan, develop, and govern their regions. As this law is implemented it creates opportunities to address sustainable resource use and climate mitigation and adaptation among the relevant economic sectors operating locally. The tourist sector, for reasons described in the report, might be amenable to more creative and flexible strategies that empower municipalities and civic and commercial interests in conducting regional planning and applying for funding.

New municipal elections were held in March 2018 and the transition of power has been peaceful. However, most of the decision-making process is still conducted at the central level due to evolving capacities at the municipal level. Municipalities have been given new responsibilities while still possessing the same resources and capabilities, limiting their ability to effect genuine change. The municipalities continue to rely on their technical partners, such as the Southern Development Council, to formulate strategies, but there is growing confidence at the local level. Regional directorates on water, electricity, and wastewater are filling their role in drawing policies and formulating projects. The data that ISTI researchers requested from utility managers was professionally and technically managed by well-educated technocratic teams. This enabled a highly successful data gathering process that may not be typical of other countries.

The overall focus in the country was both on national priorities and the needs of local citizens, as represented by their newly-elected municipal governments. Municipalities have recently formed committees that are organized based on function (waste, water, tourism, etc.), and are making strides in organizing themselves to become more effective. Decentralization is a gradual process and is estimated by policy makers to take 5-10 years to be fully in place.

At the national level in Tunisia, there is little coordination between the Ministry of Tourism and Handicrafts and Ministry of Environment (MoE). In fact, the only governmental institution that has a MoE focal point in Tunisia is the Ministry of Agriculture. This is due to the fact that the primary focus in national dialogs in Tunisia is on marketing tourism, relegating sustainability goals to lower level considerations between Ministries. This is not atypical and is symptomatic of a larger problem. While governments have long discussed sustainable tourism as an important part of their National Tourism Administrations' (NTAs) objectives, only 11% of NTAs are implementing national policies related to environmental sustainability (UNWTO, UN Environment, 2018). Very few countries in the world have formally linked their Ministry of Environment to the effort to promote tourism via tourism ministries (Epler Wood, 2017). As a result, resource use and climate change mitigation and adaptation issues generally fall between the cracks of the two agencies, and priorities are not set

according to these issues. In Tunisia, this does not imply that the Ministry of Tourism and Ministry of Environment do not cooperate on environmental projects. There are strategies and think pieces related to climate change and tourism, and the national climate change strategy addressed the tourism sector. However, sustainability and climate change are not as yet mainstreamed into the country's national tourism policies. Collaboration between the MoE and the Ministry of Tourism remains at an ad-hoc level and is not embodied in organizational structures that sustain this cooperation on a regular basis.

The National Tourism Office (ONTT) is the main actor designing and implementing communication and marketing campaigns for the tourism sector. ONTT spends most of its budget on marketing, advertising, and communication campaigns for the tourist sector. Sixty-four percent of its marketing budget is spent on targeting potential tourists in Germany, the UK, Italy, and France. The remaining marketing budget is spent on secondary markets in Belgium, the Netherlands, Luxembourg, Spain, Switzerland, and the Arab countries (Mabrouk et al., 2008). The budget is allocated for promoting tourism within Tunisia through 19 international offices. This offers little scope for managing the environmental impacts of tourism on a regional or local basis.

In 2015, the Ministry of Tourism introduced a new sectoral development strategy, Vision 3+1. Its goal is to improve the quality of tourism services and allow for a sustainable form of tourism to emerge. Among the reforms is restructuring the Tunisian National Office for Tourism (ONTT), which will maintain its focus on promotion and training, but will also be given a mandate to attract investment. The strategy comprises four central pillars: product diversification in line with regional specifics, quality and training, tourism promotion, and sector modernization. The Vision 3+1 strategy emphasizes environmental quality as one of the quick wins to prioritize. The ONTT specifically identifies the tourism sector's two main challenges related to environmental deficiencies: the overuse of natural resources, and the mismanagement of municipal waste generation and its impacts on tourism [1]. But no formal mechanisms are in place to manage these issues.

Tunisia's Tourism Sector and Climate Change

In its NDC, Tunisia places tourism among the six key areas most vulnerable to climate change impacts, and stresses that most of the actions/ activities required to combat these impacts lie with "intangible investments to support and popularize new practices (institutional support, capacity building, research and development)." As an area that faces high levels of water scarcity, Tunisia is particularly vulnerable to climate change impacts. Decreases in conventional water resources due to unfavourable precipitation patterns and sea level rise are estimated at approximately 28% by 2030 (NDC Tunisia, 2015). While tourism is not a first priority for climate action in Tunisia, the country's tourism sector is threatened by coastal erosion, heat waves, and water stress. The decrease in GDP due to the impacts of climate change on the tourism sector has been estimated at 0.28%

[1] ONTT Powerpoint on Tunisian Tourism Strategy, Vision 3+1

per year, resulting in thousands of jobs lost. Hotels near the coast, with a total capacity of about 30,000 beds, will most likely face a decrease in activities due to coastline retreat (ibid).

With its NDC, Tunisia has committed to reducing its economy-wide carbon intensity by 41%[2] in 2030 relative to 2010. Under this commitment, Tunisia has estimated that its emissions will be 42.4 MtCO2eq in 2030 instead of 68.2 MtCO2eq in the baseline scenario. The energy sector will contribute 85% to this reduction in carbon intensity: 40% through increased energy efficiency and 45% through renewables. Buildings and transportation will account for 66% of the target for energy efficiency, areas the tourism sector will be required to contribute to.

Methodology

The project was conducted over 18 months in order to gather both science-based data and policy data. A summary of the methodology followed is shown below:

Phase of Research	Description
Phase 1 Viability of data collection	Test the viability of the data collection protocol for the new *ISTI Framework*, working with local authorities. This process involved Harvard researchers and a local research counterpart
Phase 1 Creation of revised data platform	Researchers responded to the specific challenges for gathering data locally, reviewed the ISTI Framework for responsiveness to local data sources, and designed the data-gathering program to respond to these challenges.
Phase 1 Synthesis	Tested the feasibility of gathering the data locally, working with local researchers, and sorted out local issues with obtaining data via agreements with local institutions
Phase 2 Data collection	Full data gathering exercise in Tozeur and Djerba, working with local research partner and local authorities to fully populate the ISTI framework indicators and develop a set of outcomes that will guide local authority decision making on resource use, mitigation planning, and adaptation
Phase 2 Policy Research	Expert in Arab region/Tunisia policy undertook analysis of relevant Tunisia policies for managing tourism impacts using the preliminary results from the ISTI data-gathering exercise
Phase 2 Data and Policy Analysis	Data and policy researchers collated and analyzed data
Phase 2 Stakeholder Workshop	Tunisian researchers, business, government, and civil society members gathered for research results session with discussion of results and policy pathways
Phase 2 Final Report	Researchers finalized report based on data gathered, policy analysis, and local workshop

[2] This is the aggregate of Tunisia's unconditioned and conditioned target.

After an onsite reconnaissance visit in July 2017 and discussions with local stakeholders, researchers undertook a second analysis of the indicators within the ISTI Framework to define their relevance to the specific context. A couple of indicators were considered non-applicable and the rest of the indicators were translated to a list of questions to be addressed to the relevant agents. Collaborations with local institutions were established. Data were initially requested from public agencies (e.g. utilities providers). To complete data gaps, a survey aiming at representative segments of the tourism private sector was designed and took place by means of onsite interviews in May 2018. Where the response rate assumed enough representativeness of the segment questioned, or the interviews revealed a relatively common trend (e.g. the use of taxis by tourists), data were extrapolated to the whole segment according to monthly tourist nights and relevant assumptions. Table 1 presents the representativeness of the survey results among hotels. Apart from hotels, managers of travel agencies and recreational activities and taxi drivers were also interviewed. During the data analysis, priority was given to data acquired from public agencies, as these are likely to bear a higher level of certainty. Public agencies that provided data include utilities for electricity and water supply (STEG and SONEDE, respectively), wastewater treatment (ONAS), freshwater resources management (CRDA), and national agencies such as the Tunisian Organisation for Tourism (ONTT), municipalities, and others. A parallel research in literature and previous assessments took place to fill knowledge gaps and provide a better understanding of individual issues.

Data acquired in Djerba were more robust compared to Tozeur, hence the testing of the ISTI Framework was mainly based on the research results from Djerba. The data acquired in Tozeur did not allow for a coherent implementation of the ISTI Framework, however it was possible to make a quantitative/qualitative analysis of the main issues and risks in Tozeur while reviewing how data management can assist local decisions makers in the region.

Following the data analysis, a workshop took place in Djerba to present the results to local stakeholders and get feedback that was then used as the basis for the development of a set of recommendations for local authorities.

***Table 1**. Hotel Survey in Djerba*

Hotels	Total bed capacity	%	Interviewed[3] (bed capacity)	Data acquired (bed capacity)	Representativeness (bed capacity)
5-stars	3,927	11.0%	2,179	1,759	45%
4-stars	17,840	49.8%	5,141	5,141	29%
3-stars	8,022	22.4%	2,010	2,010	25%
1, 2-stars, other	6,040	16.9%	0	0	0
Total	**35,829**	100.0%	9,330	**8,910**	**25%**

[3] Twelve hotels were interviewed out of which eleven provided data.

Djerba

Tourism in Djerba

Tourism in Djerba has been a major economic activity since the government issued a decree establishing the delineated Tourist Zone in the north-eastern part of the island and provided financial incentives to the private sector to develop tourism infrastructure, mainly accommodation units. Djerba has the highest bed capacity in Tunisia and gathers more than 20% of total tourist overnight stays in the country. During the last decade the island's tourism sector was harshly hit by two events: the popular revolution in late 2010-early 2011 and two terrorist attacks in 2015 that took place in Tunis, Tunisia's capital, and Sousse – two major Tunisian tourism destinations. As shown in Figure 1, tourist nights in Djerba in 2011 and 2015 were less than half than in 2008-2010 and 2012-2014 respectively. Presently, the sector appears to be slowly recovering, as shown by the number of tourist nights in 2016 and 2017. The question raised by this research project is if science-based data on the use of natural resources by the tourism industry can help Tunisia protect the assets that tourism depends on and contribute to the sector's recovery.

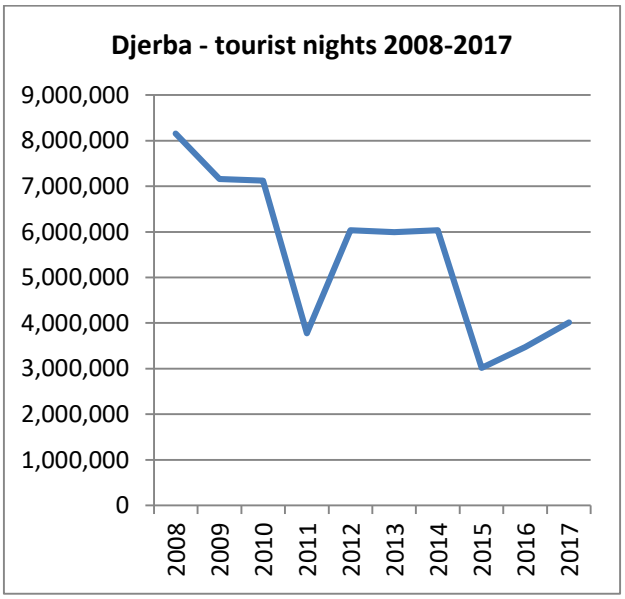

Figure 1. *Tourist nights in Djerba for the period 2008-2017 (Data source: ONTT)*

Data Analysis and Results

The following sections elaborate on the most impacting categories and highlight major findings.

Energy – Stationary Energy[4]

Research related to the questions of how governments manage the costs of tourism-related energy use have been raised in the literature based on evidence from research primarily by Harvard students whose case studies in their home countries revealed a range of issues with the management of energy and other utilities

[4] ISTI Framework Indicators EN.01 Appendices1, 2, 3

for tourism (Epler Wood, 2017). Continuation of this research revealed further evidence of the problem of peak utility costs driving up local energy costs – via investigations of global case studies and interviews with informed experts (Epler Wood, Milstein and Ahamed-Broadhurst, 2019). Results indicate that, indeed, most governments worldwide do not know the extent to which tourism is driving up energy costs at the destination level. Nor do they know to what extent peak energy demand for tourism in high seasons is driving requirements for more power generation, which can require costly additional energy infrastructure that may not be compatible with meeting climate goals (ibid). Accounting for the costs of managing energy for tourism at specific destinations, including the costs of shifting to alternative energy, will allow governments to understand their investment needs effectively and with precision.

Electricity

In Tunisia, the energy mix for power generation consists of 92.3% natural gas (Tunisia 2nd Biennial Report to the UNFCCC, 2016). Tunisia largely imports its primary energy, with 56% of natural gas consumption in 2015 covered by domestic production and the remaining 44% imported (ibid). High-energy imports, in combination with the weak national currency, results in a highly subsidised energy sector, which in 2015 accounted for 7% of GDP (ibid). Power generation for Djerba's electrification takes place in Gabes, Tunisia and is 100% natural gas-based. Electricity is transmitted from Gabes to Djerba through a high-tension network and transformation to medium tension takes place at a transformation station in Djerba. An oil-based power generator located on the island serves only in emergency situations. The share of renewable energy in power generation in Djerba is nearly zero, despite the fact that the island receives around 33,000 hours of sunshine per year: a rate that is one of the highest in the Mediterranean and thus represents an enormous potential for solar electricity generation.

The average electricity demand by the tourism sector in Djerba is lower in winter months due to a low volume of tourists, with tourism's demand as low as 15.4% of total island demand during the month of February. This increases to 56.5%[5] of total island electricity demand in the summer due to a high number of tourists (Figure 2)[6]. But per tourist night electricity use is higher in the winter due to the requirements of the season and largely inefficient hotel operations, due to a low number of guests, reaching 42KWh during the month of January. On the contrary, per tourist night usage is lower during the tourist period, with average demand at 21KWh[6] during the months of August and October due to high occupancy rates and greater economy of scale. The annual per tourist night average for 2016-2017 was estimated at 29KWh. This is significantly higher than previous estimates for the average per tourist night electricity demand in Tunisia, which ranged from 13.7 KWh to 20Kwh per tourist night for 1997-2006 (ANPE, GTZ, 2010). Total annual electricity demand by the tourism sector equalled approximately 88.3 GWh in 2017, which is nearly one third of total annual electricity demand of all consumers on the island. One way to put this into perspective for decision makers is by using

[5] The percentages and per tourist night electricity demand are averages for the years 2016 and 2017.
[6] The methodology followed to assess electricity demand by tourism is included in Authors' supplementary material

the 'population equivalent' of tourism; that is, the ratio of tourist-nights to resident nights over a year. In 2017, tourist nights in Djerba were 4.017 million, hence the tourism population equivalent was roughly 7% or equivalent to 11,000 residents. This means that the equivalent of 7% of the population (tourists) consumes one-third of total electricity and the remaining two-thirds is consumed by the 160,000 residents and other economic sectors.

Among the interviewed hotels, 4-star hotels appear to achieve higher operational efficiency, with significantly lower fluctuations across the year, especially when compared to 5-stars hotels (Figure 3).

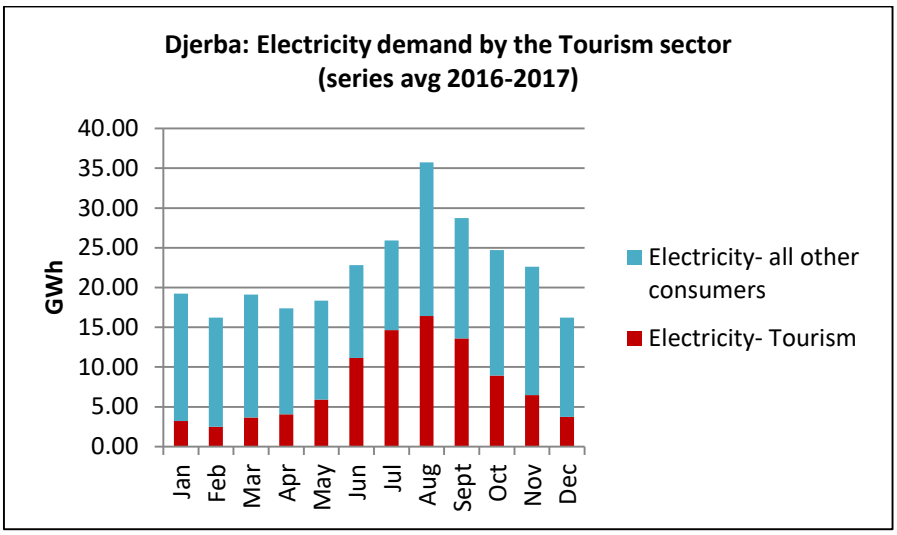

Figure 2. *Tourism's electricity demand in Djerba*
(Data source: STEG, Airport, Private sector survey)

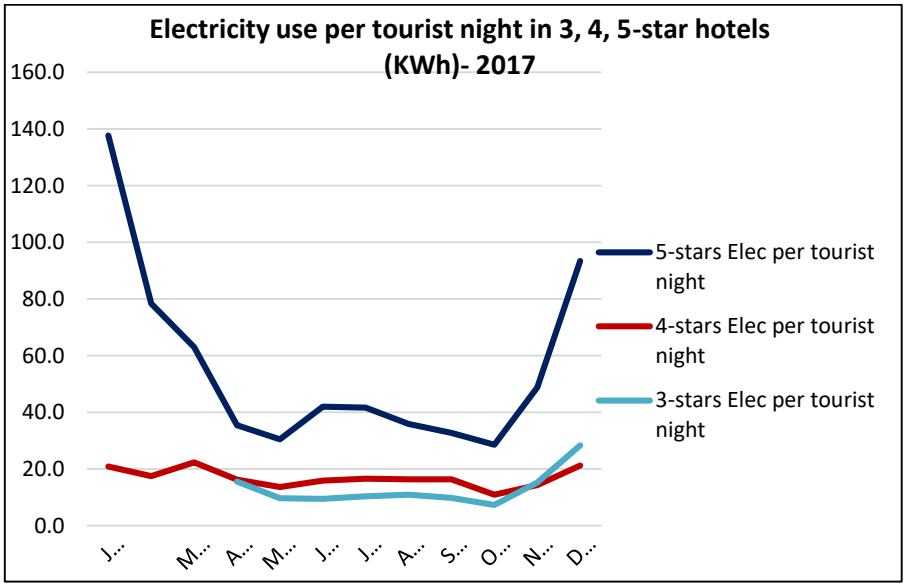

Figure 3 *Per tourist night electricity demand (Data source: Private sector survey)*

Tourist arrivals in Djerba present seasonal patterns, with a peak period in July and August (Figure 4). These two months, being the warmest of the year, drive increased electricity demand for air conditioning spaces where tourists are hosted (e.g. hotels, airport). This has important economic implications for power generation infrastructure, which needs to be adequately sized to cover peak demand.

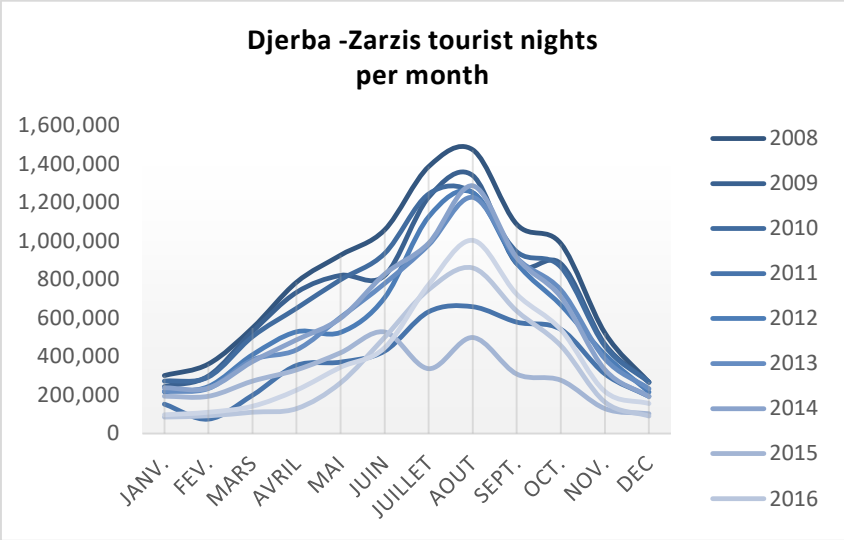

Figure 4. *Tourist nights per month for the period 2008-2016 (Data source: ONTT)*

The projected warming of the climate will most likely exacerbate current trends in peak power demand. To examine the impact of climate variables on electricity demand by the tourism sector, data on the monthly electricity demand by tourism and total overnight stays obtained for 2017 were used to generate 3 regression models for each of the hotel categories under consideration: 5, 4, and 3 stars, respectively. As was previously done, for instance in the studies by Cortés-Jiménez and Pulina (Cortes-Jimenez et Pulina, 2010) and Gómez-Calero et al. (2014), total overnight stays were used as a proxy to measure tourism. For electricity demand and overnight stays, figures were expressed in natural logs. Average monthly temperature and relative humidity were included to account for possible differences in energy consumption associated with differences in climate conditions. The general descriptive model for the relationship between tourism and hotel electricity consumption can be expressed as follows:

$$E = \beta + \beta_1 * N + \beta_2 * T + \beta_3 * H$$

Where E is the hotel electricity consumption expressed in logarithms, N is the monthly average overnight stays spent in hotels belonging to the category of interest expressed in logarithms, T is the average monthly temperature in Djerba expressed in Celsius, and H is the average monthly relative humidity expressed as a ratio of the current absolute humidity to the highest possible absolute humidity. The formulas describing the relationship for each hotel category are found below. Appendix 4 includes the regression model results.

For five-star hotels:

$$E = 13.62 + 0.017*N + 0.084*T - 5.40*H$$

For four-star hotels:

$$E = 6.19 + 0.60*N + 0.022*T - 0.34*H$$

For three-star hotels:

$$E = 9.42 + 0.025*N + 0.13*T - 2.84*H$$

The validity of these models was assessed through the comparison of R-squared to 1[7]. Since all three R-squared values for the models generated are greater than 0.9 (see Appendix 4), we are confident that these models accurately assess the relationship between hotel electricity consumption, hotel overnight stays, temperature, and humidity. However, to improve the quality of these models, future assessments could also consider hotel surface as an additional parameter that could influence electricity demand.

These models can be used to predict future hotel electricity consumption based on temperature estimates. Under the Koppen Climate Classification, Tunisia belongs to the Mediterranean region. This region is projected to be among the most heavily affected by twenty-first century greenhouse gas-induced climate change, with significant regional warming and drying by the end of the century (Mariotti et Dell'Aquila, 2012). It is estimated that the mean summer temperature in the Mediterranean region will increase by 2°C by 2039 (USAID, 2015). This temperature increase is considered quite plausible for Djerba, given that the average temperature increase on the island has been almost double the global average (Figure 5). Using 2°C as an average estimate of temperature increase, along with the overnight stays and humidity recorded for July 2017, we calculate that the electricity consumption of hotels in Djerba in 2039 will be 424,839 Kwh for five-stars, 328,748 Kwh for four-stars, and 188,701 Kwh for three-stars. For comparison, in July 2017, these values were 359,140 / 314,597 / 145,498 for five, four, and three-star hotels, respectively. This is up to an 18%, 4%, and 30% increase in electricity demand for five-stars, four-stars and three-stars, respectively (Figure 6).

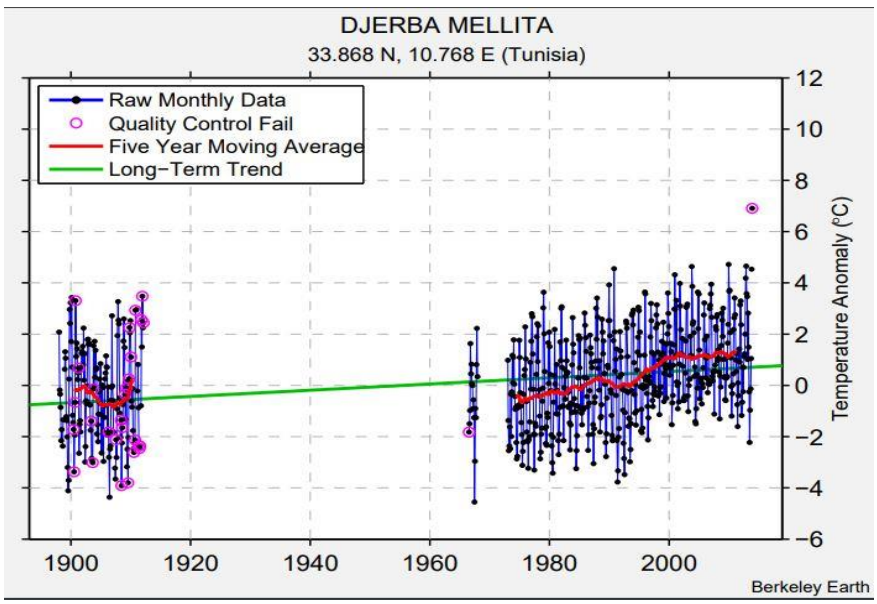

Figure 5. *Temperature Anomaly observed in Djerba between 1900 and 2015.*

[7] R-squared is the coefficient of determination and represents the percentage of the hotel electricity consumption variation that is explained by the model.

(Source: Berkeley Earth)

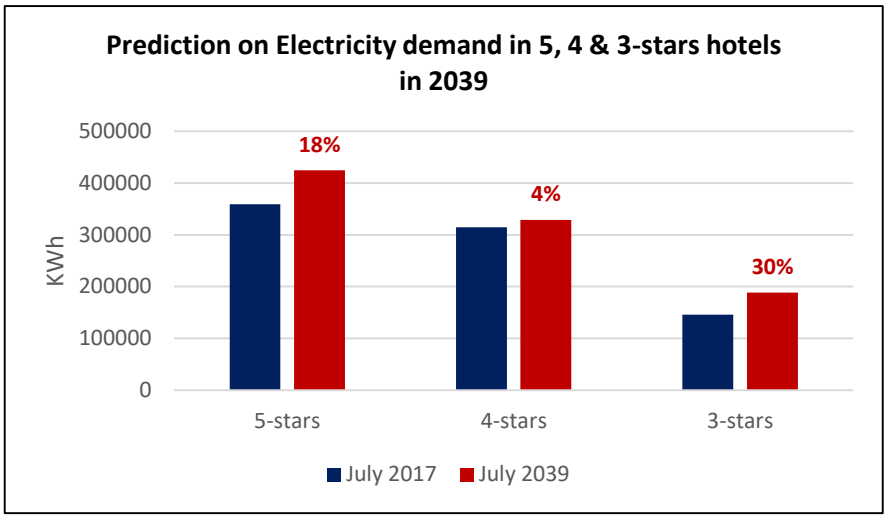

Figure 6. *Hotels electricity demand 2017 /2039 prediction (Source: Authors' modelling)*

LPG[8]

Liquefied Petroleum Gas (LPG) is used in accommodation units for heating spaces during the winter period, heating water and cooking throughout the year, and in some cases, for heating pools. LPG is a petroleum product that is entirely imported into Tunisia and entails high subsidisation costs. Most LPG usage relates to heating water, either for heating spaces or sanitary use, hence solar thermal energy could potentially be an alternative to LPG.

Data on LPG consumption were collected from hotel managers. Ten hotels, representing 29% of all tourist nights in Djerba in 2017, provided data.[9] When in operation, the average consumption of LPG per guest night ranges from 0.81kg to 11.43kg. Consumption does not seem to increase with hotel category, with four-star hotels appearing to have the lowest consumption levels (Figure 7). Three and five-star hotels present similar rates, however, the low representativeness of the three-star category in the sample limits confidence in this conclusion.

[8] ISTI Framework Indicator EN.01.5

[9] Nine out of eleven provided data for both 2016 and 2017, and the remaining two provided data for one of the two years. Ten of eleven hotels provided consumption data per month and one hotel provided consumption per year. The data from one hotel were removed from the calculation as they were abnormally high. For the hotels that provided data for both years the average was taken, except in one case that was deemed an outlier and the most conservative value of the two years was taken.

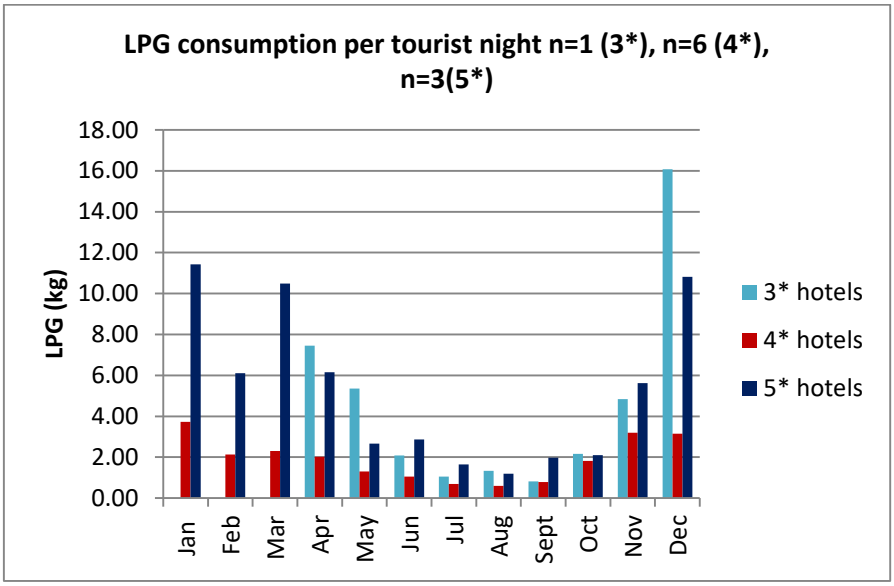

Figure 7. *Per tourist night LPG consumption, year 2017 (Source: Private sector survey)*

Water[10]

Heavy demands on local freshwater resources during the driest seasons of the year force countries to allow water use when water scarcity is of grave concern for local residents. Hotels located in destinations around the world have increasing water risk factors, in part due to water scarcity and in part due to high water consumption by tourists[11] .

With 200mm average precipitation per year, Djerba is a water-stressed area with very limited natural freshwater resources. The island has no surface freshwater resources and underground resources have been over-exploited for a significant period of time (Figure 8). In addition, sub-surface freshwater resources are of poor quality, with salinity ranging from 2.5g/l to 8g/l (CRDA, Medenine), and rates as high as 17g/l have been recorded in the past (Kharroubi et al., 2012). Seawater intrusion has been identified as the main reason for the salinization of coastal aquifers (ibid) – a result of pumping rates that exceed aquifers' capacity for natural recharge.

[10] ISTI Framework Indicators WA.01, WA.02, WA.03, WA.04, WA.06, WA.07

[11] Countries at highest risk are: Indonesia, India, Thailand, China, the United Arab Emirates, and the Philippines. Seven destinations are at the highest risk of running out of water in the driest seasons within these countries: Bali, Jakarta, Mumbai, Dubai, Istanbul, Zhengzhou, and Abu Dhabi. International Tourism Partnership (ITP), August 2018, ITP Destination Water Risk Index, International Tourism Partnership, London, UK .

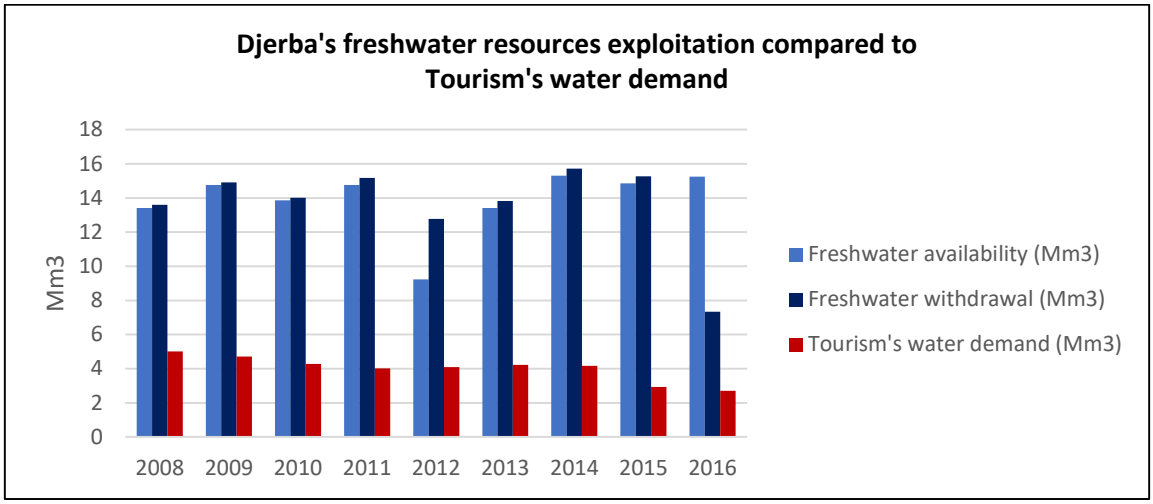

Figure 8. *Groundwater (unconfined and confined aquifer) withdrawal in relation to availability (Source: CRDA Medenine) and tourism's water demand (Source: municipal water supplier SONEDE)*

In 2017, tourism was responsible for 25% of SONEDE water consumption (Figure 9), with average per guest night consumption equal to 766lt. However, actual per tourist night water consumption may be higher than this, given that some hotels operate private wells, the water withdrawal of which is not recorded. Among the eleven hotels interviewed, representing three-, four-, and five-star categories, average per tourist night SONEDE water consumption ranged from 420lt to 2760lt and it appears there is no particular trend between hotel category and lower or higher consumption. In addition, the rates of water consumption by tourism in Djerba appear to be higher than what has been reported for other Mediterranean destinations. For instance, average per guest-night water consumption was found to be:

- 174-361L/g.n. in hotels in Benidorm, Spain from one to four stars (Rico-Amoros et al., 2009);
- 541L/g.n. in 196 hotels in Mallorca (Tortella & Tirado, 2011)
- 250-600L/g.n. in Morocco hotels, depending on the hotel category (Eurostat, 2009)
- 225-496L/g.n. in 63 hotels in Cyprus, ranging from hotel-apartments class B to five-star hotels (Hadjikakou, 2014)

Moreover, during the last decade, average per tourist-night water consumption appears to be inversely proportional to tourist nights (Figure 10). This means that 'water productivity,' namely the income output per unit of water consumed (Hadjikakou, 2014), is decreasing when tourist numbers decrease; a failure to achieve economies of scale. The gradual recovery of the tourism industry to pre-revolution figures will most likely increase per tourist night water efficiency; however, this should not be misinterpreted, as even during 2008, a year of high tourism arrivals, per tourist-night water consumption was 614lt, which is still high considering the water availability context of the island.

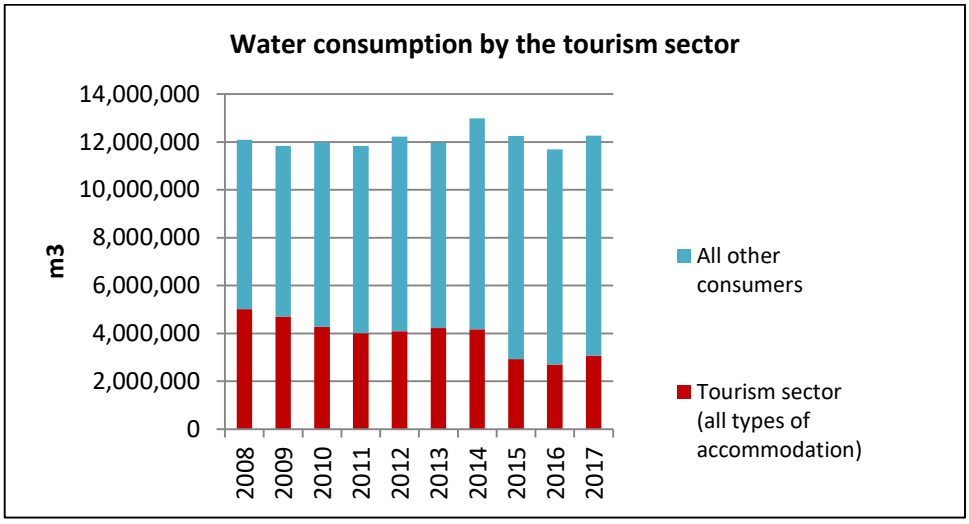

Figure 9. *Tourism's water consumption for the period 2008-2017 (Data source: SONEDE)*

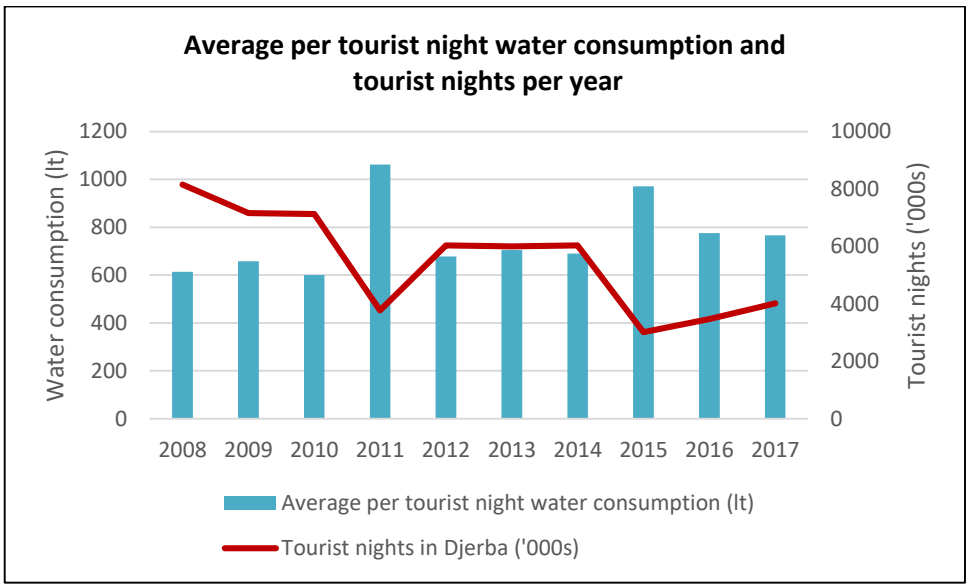

Figure 10. *Per tourist night water consumption in relation to annual tourist nights (Data source: SONEDE, ONTT)*

In 2015, total water consumption from all users in Djerba (excluding agriculture) was 12,243,500m3 (SONEDE data), out of which, 6,538,739m3 (ANPE, 2016) were produced by the desalination of brackish underground water. Until 2018, the island's municipal water needs were supplemented by water transported through pipes from Medenine. However, in 2018, a new 72 million USD desalination plant was inaugurated in Djerba: the first desalination plant in Tunisia that treats seawater. With an ability to produce 50,000m3 of water per day and potentially expandable to 75,000m3, the island's potable water demand could now be covered entirely by desalination. The water-energy nexus makes Djerba's water demand very relevant in terms of its GHG emissions and contribution to climate change. The new desalination plant requires 4.5KWh of electrical energy for the production of 1m3 of potable water, including pumping and reverse osmosis procedures (SONEDE, 2015). This means that the per tourist night water consumption equal to 766lt requires an average energy use equal to 4KWh, which is roughly equivalent to 20% of the per tourist night electricity use in tourism establishments during the month of August (see section on Stationary Energy). Fostering water efficiency in

tourist accommodations and using renewable energy to power desalination could alleviate the pressure that water demand in Djerba puts on the local power generation system.

To date, there has been no research that examines the correlation between the impact of climate variables and water demand by the tourism sector. Data on water consumption acquired in Djerba were used to examine this relationship. More specifically, data on monthly water consumption and total overnight stays obtained for 2017 were used to generate a regression model. The general descriptive model for the relationship between tourism and hotel water consumption can be expressed as follows:

$$W = \beta + \beta_1 * N + \beta_2 * T + \beta_3 * H$$

Where W is hotel water consumption expressed in logarithms, N is the monthly average of overnight stays spent in all hotels in Djerba expressed in logarithms, T is the average monthly temperature in Djerba expressed in Celsius, and H is the average monthly relative humidity expressed as a ratio of the current absolute humidity to the highest possible absolute humidity. We used the monthly water consumption figures obtained for 2008 through 2017, to which we added the well water consumption figures derived by a trend reported by some hotels. In doing so, we were able to estimate the following regression equation:

$$W = 5.33 + 0.528 * N - 0.001 * T + 0.896 * H$$

As was described in the electricity model section, the average summer temperature in the Mediterranean region is expected to increase by 2°C by 2039. Therefore, for prediction purposes, we used 2°C as an average estimate of temperature increase. We maintained the overnight stays recorded for July 2017 and found that the water consumption of July 2017 (382,722m^3) would increase to 422,557m^3 by 2039 (Figure 11).

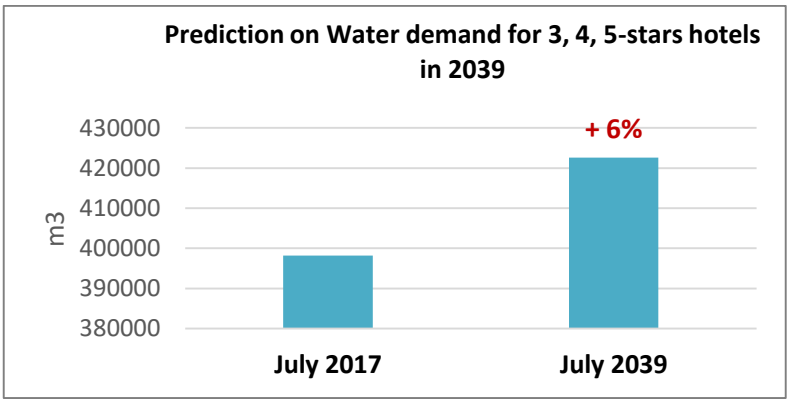

Figure 11. *Predicted future water demand by the tourism sector (Source: Authors' modelling)*

Wastewater treatment [12]

Across the globe, wastewater treatment infrastructure is underdeveloped or entirely lacking. Only 8% of populations in low-income economies have wastewater service. In lower middle-income societies, only 28%

[12] ISTI Framework Indicator WS.02

of the population has service. Even in upper middle-income countries, only 38% of the population has access. Only developed, high-income countries have widespread wastewater treatment services for their populations that goes above 70% (UN Water, 2017).

There are three operating wastewater treatment plants (TPs) in Djerba: in Aghir (Midoun), in Houmt Souk, and in Sidi Mehrez, putting this destination well ahead of many lower middle-income economies in terms of percentage of service. Data were provided by the local branch of the National Office for Sanitation (ONAS: Office National de l'Assainissement) for all three TPs (Table 3). In addition, there are a number of hotels that treat their own wastewater, but there is no record of this data. Among the twelve hotels surveyed, four hotels (two five-star and two four-star) reported private TPs on their premises.

The level of treatment is tertiary in the TP of Aghir and secondary in the other two. The ONAS data make no distinction among different users of the sewage system, so there are no readily available data for tourism-related wastewater production. In addition, there is no separate storm water collection system in Djerba, which means that wastewater data include runoff water as well. We assume that this is not likely to have a significant impact in the current assessment given the low annual precipitation rates, the isolation of the tourism area, which does not include other significant uses (e.g. agriculture), and the fact that tourism occurs mainly during the driest period of the year.

The tourism zone is served by the TPs in Aghir and Sidi Mehrez and tourist nights are the main driver of wastewater production in these plants (Figure 12). However, a small number of residences in this area (mainly Aghir's) are connected to these plants. It is possible to make an estimation of the portion of treated wastewater that is attributed to residences by looking at the months of low tourism (Table 2). Indeed, during December and January tourist nights are not the main driver of wastewater production as tourism's water consumption is far less than wastewater production (Figure 12). At the same time, during these months tourism's water consumption is a good indicator of tourism's wastewater production, as water use for irrigation in tourism facilities is likely to be minimal; these two months present the highest annual precipitation in Djerba. Taking January as a proxy, Table 2 shows the estimation of wastewater attributed to residences in the tourism area.

Table 2. *Wastewater production and tourism water consumption during low-tourism period*

	Jan 2017
TP wastewater production Aghir (m3)	145385
TP wastewater production Sidi Mehrez (m3)	8246
Total TPs Aghir & Sidi Mehrez (m3) (a)	153631
Tourism's water consumption (m3) (b)	100929
Wastewater attributed to residences in the tourism area (a-0.8b)*	72888

**Tourism's water consumption was deducted by 20% to account for water not going through the sewerage system*

Based on the above assumptions, in 2017 tourism was responsible for 57% of wastewater production, with average production per tourist night of 690lt. At the scale of the whole island, these figures need to be considered along with the fact that the rate of connection to the public sewage network in Djerba is very low. According to data in previous assessments, the rate of connection in Djerba was 33% (ANPE, 2016). In comparison, the average national connection rate in urban areas is 90%, with 57% of the total population in Tunisia having access to the sewage network (ONAS official statistics). Specifically, the connection rate in Djerba is 100% in the tourist areas, but much lower in purely residential areas. Only 50% of residences are connected (more in cities, fewer outside cities) due to the fact that local people cannot afford the connection cost.[13] Although tourism's wastewater is entirely treated, the detrimental effect resulting from the lack of connection in other areas will likely be exacerbated as the tourism workforce returns to the island with the sector's gradual recovery.

The rate of water reuse in Djerba is low and it mainly relates to the production of the Sidi Mehrez plant. Approximately 90% of treated wastewater from this plant is used for the irrigation of the nearby golf course, with little extra water required for this purpose. A low portion of the production of Aghir's TP (4.29%) is used for irrigation in nearby agricultural land. No water reuse is in place for the production of the Houmt Souk plant.

Table 3 *Wastewater production and tourism water consumption, years 2012 to 2017*

	2017	***2016***	***2015***	***2014***	***2013***	***2012***
Water consumption by tourism (m3)	3,075,208	2,695,771	2,927,047	4,166,110	4,225,244	4,091,852
Wastewater production: TPs of Aghir and Sidi Mehrez* (m3)	3,051,923	3,348,652	3,121,775	3,107,977	3,818,766	4,292,919
Water reuse (m3)	548,761	493,692	620,987	855,879	1,153,724	1,091,232
Ratio of water reuse to tourism's water consumption	17.84%	18.31%	21.22%	20.54%	27.31%	26.67%

* Only the TPs that treat waste water of the tourism zone are included; at an island scale the ratio of water reuse is even lower as water production from TP in Houmk Souk is not being reused

[13] Interview of Harvard researchers at the Wastewater Treatment Agency (ONAS: Office National d'Assainissement) in Djerba on July 14, 2017.

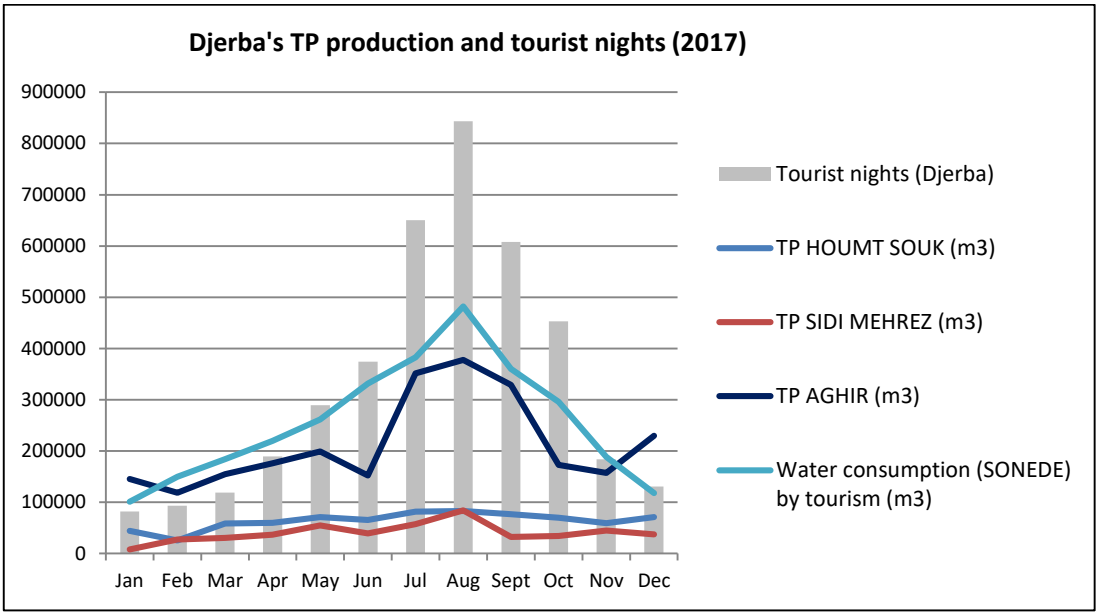

Figure 12. *Treatment plant production and tourist nights, year 2017 (Data sources: ONAS, SONEDE, ONTT)*

With the new desalination plant, freshwater supply has become more expensive in Djerba, but the quality of water has improved significantly. The minimisation of the salt content of the water supply also results in wastewater with low salt content that has the potential to be reused for non-potable purposes, such as agriculture, garden irrigation, flushing toilets, and others, if the necessary pollutant removal takes place. By discharging treated wastewater to the sea, the embodied energy, namely the energy used to remove salts from seawater during desalination, is wasted, and more energy is required for freshwater supply (Figure 13). The United Nations is now referring to wastewater as the 'untapped resource' that has the potential to be reused and reduce pressure on freshwater resources, especially in water-stressed areas (UN Water, 2017). According to ONAS[14], the TPs in Sidi Mehrez and Houmt Souk are in the process of being upgraded to tertiary treatment, improving the quality of treated wastewater and thus increasing the potential for water reuse on the island. However, there are alternatives to conventional wastewater treatment methods to be considered. Conventional systems use a high amount of energy to remove pollutants, whereas constructed wetlands appear to be a more effective technology in terms of pollutants removal, and cost less overall (Almuktar, Abed, & Scholz, 2018). These are systems that function similarly to natural wetlands that purify wastewater by naturaly absorbing and dissolving the majority of pollutants occuring in municipal treated wastewater (ibid).

[14] Ibid

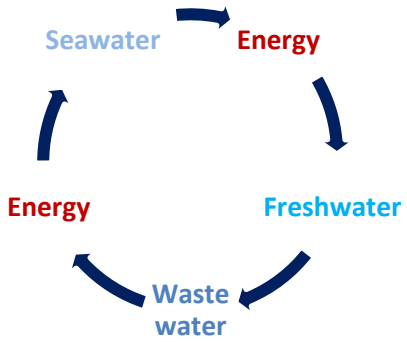

Figure 13. *The Energy-Water nexus of municipal water supply in Djerba*

Municipal Solid Waste[15]

The level of additional solid waste produced by tourism is frequently not factored into the operational costs for local municipalities. According to UN documentation only 36% of low-income countries have collection. Africa and Asia have lower percentage collection figures than Latin America, the Caribbean, Europe, and North America. Rural areas have lower rates of collection than urban areas. But even in cities in many low-income countries collection coverage is in the range of 30 to 60%, and the figures may be much lower in some countries. Overall, approximately 2 billion people, or 28% of the global population, lacked access to solid waste collection in 2015 (UNEP, 2015). It is therefore not at all surprising that cities in emerging economies and island resorts in rural areas around the world have an uncomfortable challenge ahead to find suitable landfill sites. As a result, untreated solid waste accumulates and is ultimately disposed in areas that tourists cannot observe.

On Djerba Island, there is no system for integrated solid waste management. According to data from ANGED (as presented in ANPE, 2016), Djerba had five uncontrolled landfill sites (dumping sites) in 2005, zero dumping sites in 2007 (the year that the Guellala-controlled landfill was commissioned and served the entire island), six in 2014, and ten in 2015. The landfill in Guellala operated until 2012, when it was closed due to complaints from nearby locals regarding the odour that reached their premises. To mitigate the waste management problem, a bulking unit in and a temporary disposal site was created in Aghir, in 2015. This currently serves the three municipalities via three transfer centers and hosts solid waste temporarily in bulks until a holistic solution is given (Figure 14). However, the island still contains a dozen untreated dumping sites scattered among the three municipalities, which are dangerous sites of pollution.

According to previous assessments, solid waste production in Djerba is in the range of 56000 T/a (median estimations for the years 2007-2009), 36% of which was attributed to tourism, with 2.86kg generated per tourist night (ANGED, GIZ, 2013). The drop in tourism numbers has decreased tourism's share; however, as

[15] ISTI Framework Indicator WS.01

tourism on the island is recovering, these figures are a good indicator for the municipalities to make projections on solid waste quantities generated by tourism.

For the present assessment, solid waste data were acquired from the municipalities of Houmt Souk and Midoun, as well as from a private collection company. Full data series for both locations were provided for 2016 and 2017. Data for Ajim were provided up to 2011 and extrapolations were made to assess Ajim's share in solid waste generation in 2016 and 2017. It is assumed that, being far from the tourist areas, solid waste production in Ajim has not been affected by the decrease in tourism numbers. Table 4 shows MSW collected in the three municipalities and tourism's share.

Table 4. *Municipal solid waste production in Djerba*

	Total MSW collected in Houmt Souk and Midoun (t)	**Estimated MSW collected in Ajim (t)**	**Total with Ajiim (t)**	**MSW collected in Midoun and Houm Souk Hotels (t)**	**MSW attributed to tourism (%)**
2016	38345		40801	9672.50	23.71%
2017	41207		43663	10894.10	24.95%
Avg 20082010		2456			

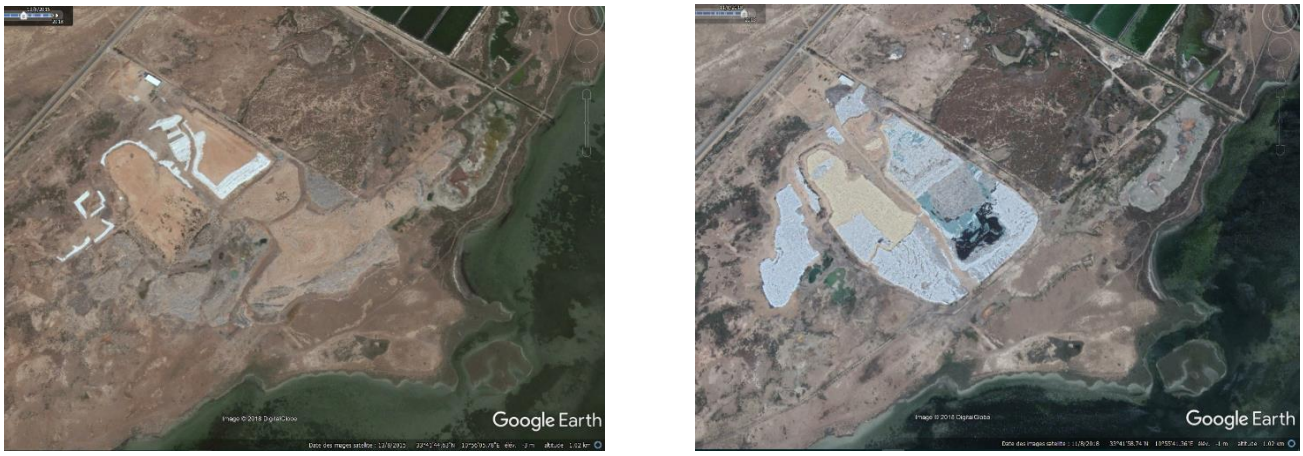

Figure 14. *Increase in area occupied by the temporary waste piling in Aghir, Djerba between 2015 (left) to 2018 (right)*

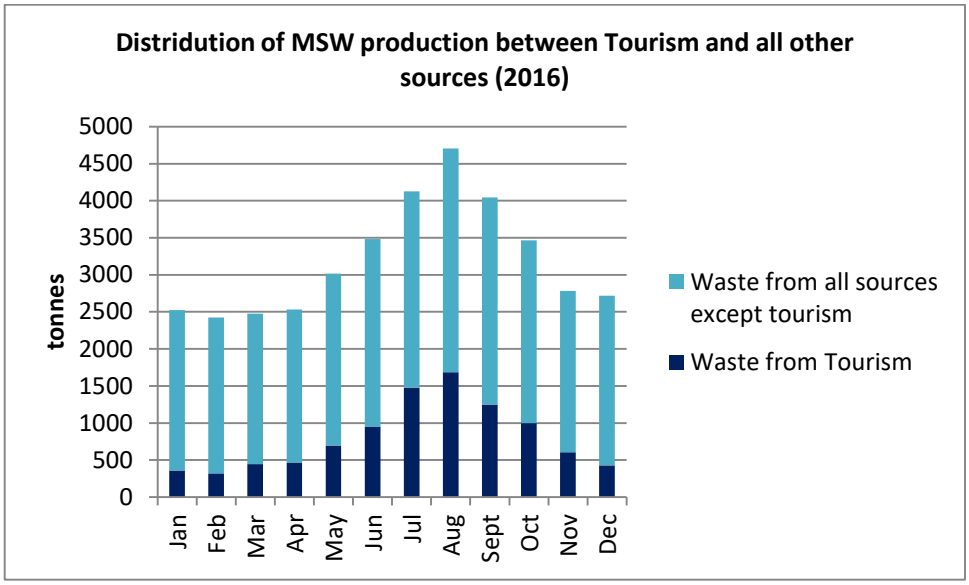

Figure 15 *(Data source: municipalities of Houmt Souk and Midoun, private collection company)*

Based on the above, in 2017 tourism was responsible for approximately 25% of solid waste production, with average production per tourist night of 2.81kg. Similarly, in 2016, tourism was responsible for 24% of solid waste production and the average production per tourist night was 3.02kg. Per tourist waste generation does not significantly differ from the assessment previously done for 2007-2009 (ANGED, GIZ, 2013), with the sole difference currently being the fate of solid waste.

The organic content of waste collected in the tourism area is higher than 60%, with a humidity of more than 70% (ibid). The organic content of waste collected in the tourism area is higher than 60%, with a humidity of more than 70% (ibid). Recycling is low in Djerba, and it mainly depends on private companies located in cities away from Djerba with operational activities not always adequate to cover the entire island. There are three companies that collect recyclables in Djerba: Ecodeck in Sfax (plastics and paper), Chaased in Tunis (glass), and Eco-olio in Nabul (kitchen oil). In addition, there is a local company that collects the residuals of grease from dishwashers from hotels for separate treatment. To date, there is no solution for garden trimmings, dangerous waste (batteries etc.), or construction waste. Due to the lack of integrated municipal waste management, hotels are required to find alternative solutions to the disposal of organic waste, and separate it from the rest of solid waste. Given that companies that collect compostables separated from the rest of solid waste are limited, it's evidence suggests that hotels do not separate out organic waste, as was reported during interviews with some hoteliers. There are three companies that collect recyclables in Djerba, all exporting recyclables to other cities in Tunisia: Ecodeck in Sfax (plastics and paper), Chaased in Tunis (glass), and Eco-olio in Nabul (kitchen oil). In addition, there is a local company that collects the residuals of grease from dishwashers from hotels for separate treatment. To date, there is no solution for garden trimmings, dangerous waste (batteries etc.), or construction waste.

The lack of integrated waste management for Djerba and the existence of uncontrolled landfills creates important implications for the health of local communities. Once waste is deposited in a landfill, it undergoes

a series of biochemical processes, which leads to the production of liquid and gaseous emissions. It has been shown that people living in the vicinity of landfills are exposed to chemical mixtures from the resulting leachate or landfill gases, which may pose significant health hazards (Forastiere et al. , 2011). To evaluate the contribution of Djerba's tourism waste on human health impacts we used the EPA's Landfill Gas Emissions Model (Land GEM) to estimate emission rates of total landfill gas and individual air pollutants from the amount of waste generated by tourism and all other sectors. Activity data for 2016 were used (i.e. waste attributed to tourism equalled 9,673 t).

This estimation is based on a hypothetical closure year of 2020 and on default emission factors in the US EPA's Compilation of Air Pollutant Emission Factors (AP-42). In the absence of site-specific test data, these factors can be used to generate emissions estimates. However, given that the dumping site in Djerba is uncontrolled, the values obtained through Land GEM are an underestimate of the actual emissions levels. While the model provides estimates for multiple gaseous emissions and pollutants, we selected benzene and carbon monoxide because of their ubiquitous release and due to the health implications associated with them (Figures 16, 17).

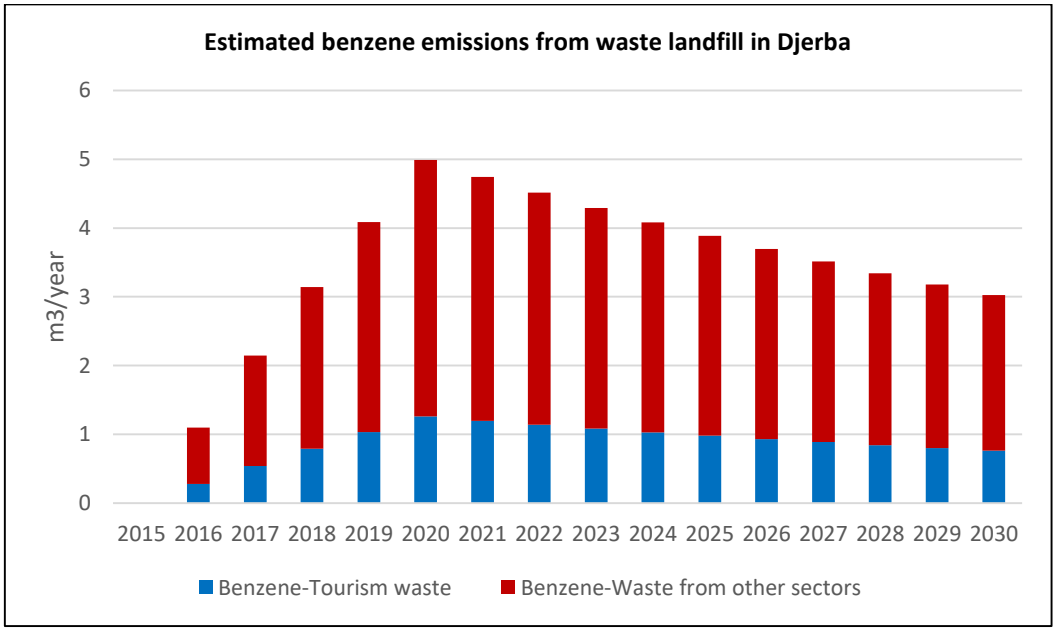

Figure 16. *Estimated benzene emissions from landfill waste* (Source: Authors' modelling)

Human exposure to benzene has been associated with a range of acute and long-term adverse health effects and diseases.[16] Benzene is a moderate eye and skin irritant. In addition, chronic exposure to benzene can reduce the production of both red and white blood cells from bone marrow in humans, resulting in aplastic anaemia (IPCS , 1993). This leaves patients feeling fatigued and with a higher risk of infections. Given its role in weakening the immune system, it is recommended to minimize exposure to benzene as much as possible. Consequently, the exposure to benzene associated with living in the vicinity of the landfill is worth noting because the World Health Organization considers that no safe level of airborne exposure can be

[16] WHO. Exposure to Benzene: A major public health concern. http://www.who.int/ipcs/features/benzene.pdf

recommended. As a result, no specific guideline value has been developed for air, which prevents us from comparing the values obtained for the landfill to any benchmark.

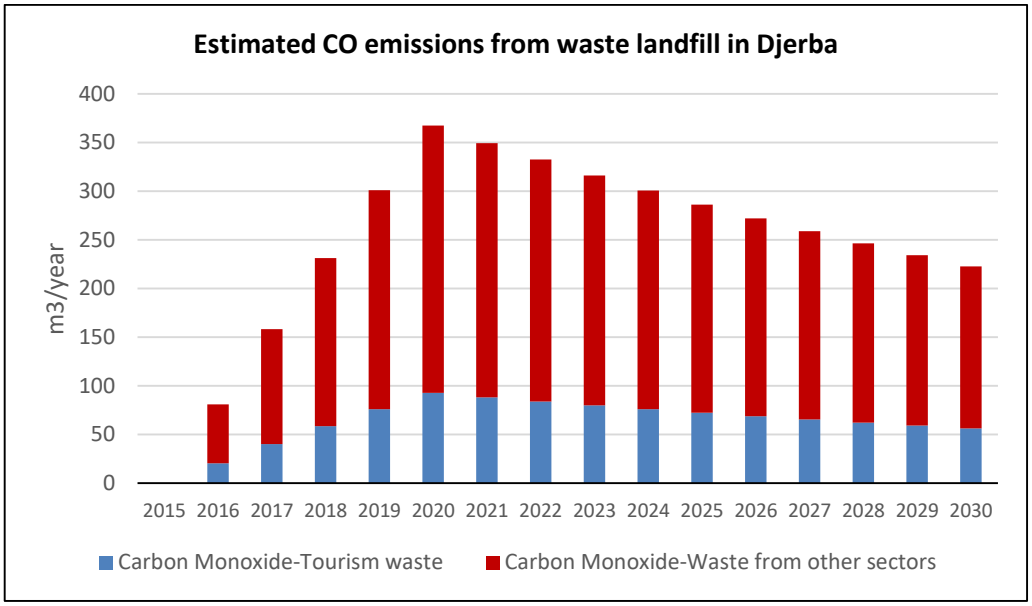

Figure 17. *Estimated carbon monoxide emissions from waste landfill in Djerba*

Chronic exposure to low levels of carbon monoxide precipitates or exacerbates already existing conditions, as it has been associated with increased hospital admissions in the elderly (Burnett et al., 1997). While levels of carbon monoxide are unlikely to get extremely high in the vicinity of the landfill, they could be of particular concern for people with some types of heart disease because these people already have a reduced ability for getting oxygenated blood to their hearts in situations where the heart needs more oxygen than usual.

In addition, several studies have evaluated the impact of waste on health for people living in proximity to waste management sites. Disposal of solid waste in a landfill causes soil, air, and water pollution, which provides a breeding ground for biological vectors such as flies, rodents, and insects. From these biological vectors, a number of diseases like diarrhea, dysentery, worm infection, food poisoning, dengue fever, cholera, leptospirosis, and bacterial infection can arise (Safaa M. Raghab et al, 2013). However, as exemplified in Djerba, the extremely low levels of pollutant emissions and the lack of exposure information limit the quality of the evidence. Based on a systematic review of the available epidemiological literature, Porta et al. conclude with a high level of confidence that the relative risk of low birthweight pregnancies is 1.06 times higher for communities living within 2km of a landfill site. Further, the authors are moderately confident that the relative risk of congenital malformations is 1.02 times higher for those communities.

Based on this assessment, the residents who are the most likely to be affected by the landfill are the ones living within 2km of the site. It thus becomes important to ascertain the number of families living within this radius in order to further quantify the health impact of the site (Figure 18).

Figure 18 *Residences in the vicinity of Djerba's solid waste discharge*

Air Pollution[17]

Tunisia does not have a system in place to monitor ambient Particulate Matter (PM) levels in cities and this poses a difficulty in evaluating the impact of a specific activity – in this case, that of the tourism sector in Djerba. The fact that Djerba uses natural gas as the source for power generation lowers the effects of air pollution. It was therefore more important to look at transport-related emissions. Air pollution caused by energy use for tourism-related activities, particularly transport, within a tourism destination, is generally an under-researched area (Peeters, Egmond & Visser, 2004; Pieri, Stamos & Tzouvadakis, 2016). A study in Mallorca that explored air pollution from tourism found that apart from meteorological variables, tourism is also a determinant in the island's PM_{10} concentrations (Saenz-de-Miera& Rosselló, 2014). Specifically, the researchers assessed that a 1% increase in tourist numbers can be related to up to a 0.45% increase in PM_{10} levels. The research question was: will the management of air pollution, and accounting for those costs per tourist, allow decision makers to judge what steps are required to cover costs while transitioning to a greener economy, as part of their commitment to the Paris Agreement and the Sustainable Development Goals (SDGs)?

Particulate matter (PM), also known as particle pollution, is a complex mixture of extremely small particles and liquid droplets that get into the air. Particle pollution can be divided in two categories: PM_{10} are inhalable particles with diameters that are generally 10 micrometers and smaller while $PM_{2.5}$ are fine inhalable particles with diameters that are generally 2.5 micrometers and smaller. Once inhaled, these particles can affect the

[17] ISTI Framework indicator AP.02

heart and lungs and cause serious health effects (US EPA, 2018). $PM_{2.5}$ are of greater concern because these particles are small enough to be deposited deep into the alveoli and trigger inflammation and even enter the bloodstream. Numerous scientific studies have linked particle pollution exposure to a variety of detrimental health effects (ibid), including: premature death in people with heart or lung disease; nonfatal heart attacks; irregular heartbeat; aggravated asthma; decreased lung function; and increased respiratory symptoms, such as irritation of the airways, coughing, or difficulty breathing.

The scientific literature reporting the association between air pollutant levels and adverse respiratory health impacts is extensive. Worldwide, air pollution accounts for 6.4 million deaths each year, which is equivalent to 1 of every 9 deaths (Landrigan et al., 2017). Children are especially vulnerable to the effects of air pollution since they often spend more time outdoors than adults and their minute ventilation is higher, so they may inhale higher levels of ambient pollution (Arbex et al., 2012). In addition, their immune system is not fully developed so they may be more susceptible to respiratory infections (Lambert & Culley, 2017). Indeed, given that the adaptive immune system of infants is still inexperienced, infants rely on innate immunity, which is generally deficient. While maternal antibodies initially provide some protection against infection, their efficiency decreases over time, making neonates and infants particularly vulnerable to respiratory infections. In addition, pregnancy may constitute a state that is particularly susceptible to toxins contained in air pollution because of high levels of cell proliferation and organ development (Klepac et al. , 2018). In the last decade, a growing body of evidence has shown the association between air pollution levels and adverse birth outcomes, such as preterm birth, low birthweight, and small for gestational age.

With the data acquired in Djerba it was possible to roughly estimate PM_{10} emissions from different sources related to tourism activity, and although the results cannot be put into context, they provide a good indication of the most polluting sources. Given that the peak of tourism activities in Djerba occurs during the summer, we estimated overall PM emissions from the summer months. The activities included in this analysis were electricity and LPG, taxi use, waste transportation, and transport related to hotels' supplies. A more holistic approach would require the inclusion of aircraft taxi emissions, but due to lack of accurate emission factors these were excluded from the calculation (for the methodology and emission factors used see Appendix 5). As shown in Figure 19, the transport of tourists with taxis is by far the main contributor to tourism-related PM_{10} emissions in Djerba.

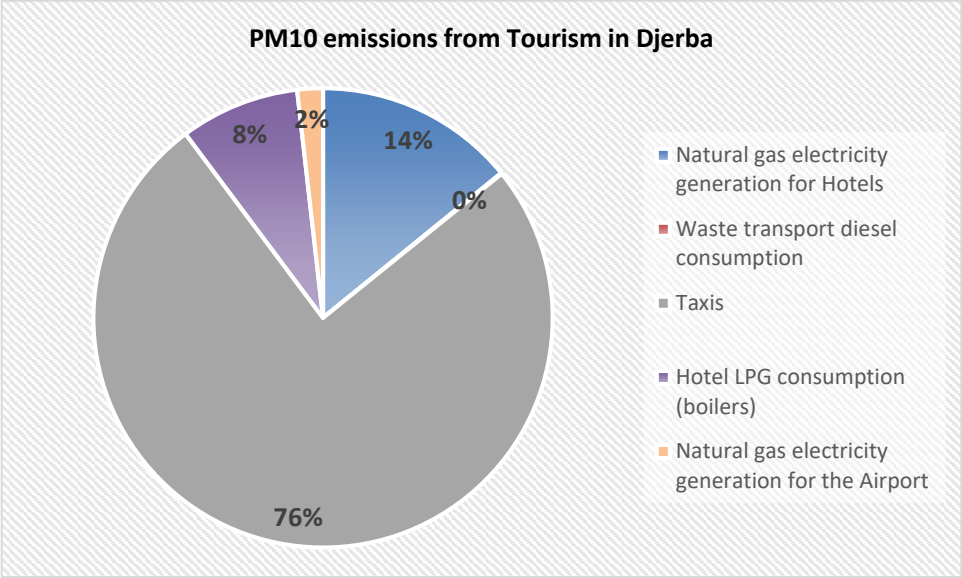

Figure 19. *Estimated particulate mater emissions in Djerba, year 2017 (Source: Authors' modeling ; Activity data source: taxis, hotels survey; Airport and MSW data)*

Land use, land use change, climate change vulnerability[18]

Tourism worldwide is set to increase by over 200% in the next twenty years, together with a 289% increase in land-use (Gössling et Peeters, 2015). Data on land-use and vulnerability presented in this section refer to existing reports, as well as on-site observations and discussions during the ISTI project. The development of tourism in Djerba had a significant impact on the distribution of land uses. The tourist zone on the island was established following Decree 73-162, dated April 5, 1973, and the production of development plans (Decree 76-759, dated August 31, 1976), and of planning rules that specified the conditions for land-use (Bourse, 2011). Following the development plan of 1985, the area occupied by tourism uses (contained within the tourism zone) was doubled, reaching 1184.57ha in coverage. Approximately 25% of previously unoccupied coastline in the tourist zone area was developed, and green spaces within the development plan accounted for only 3.5% (ibid).

Tourism development in Djerba radically changed the distribution of land uses, resulting in significant devaluation of the central area of the island (Figure 20). In addition, land cultivation is decreasing continuously. Agricultural land that was traditionally cultivated, largely around the *Menzel,*[19] using agricultural practices adapted to the local climate is decreasing annually by 5.6% (e.g. 21000 ha in 2011 dropped to 17650 in 2014). Urban and touristic development are the cause of the decrease in agriculture, as is limited water resources (ibid). The abandonment of farmland in drylands impacts the land's capacity to retain water because the irregular and limited precipitation hinders native plant colonisation, (García-Ruiz et Lana-Renault, 2011)

[18] ISTI Framework Indicators LU.01, VU.01

[19] Menzels were rural houses around which farmers and their families organised their life. Besides the residence area, a Menzel could include the silo and stable, an impluvium, areas of work, farmlands and a mosque.

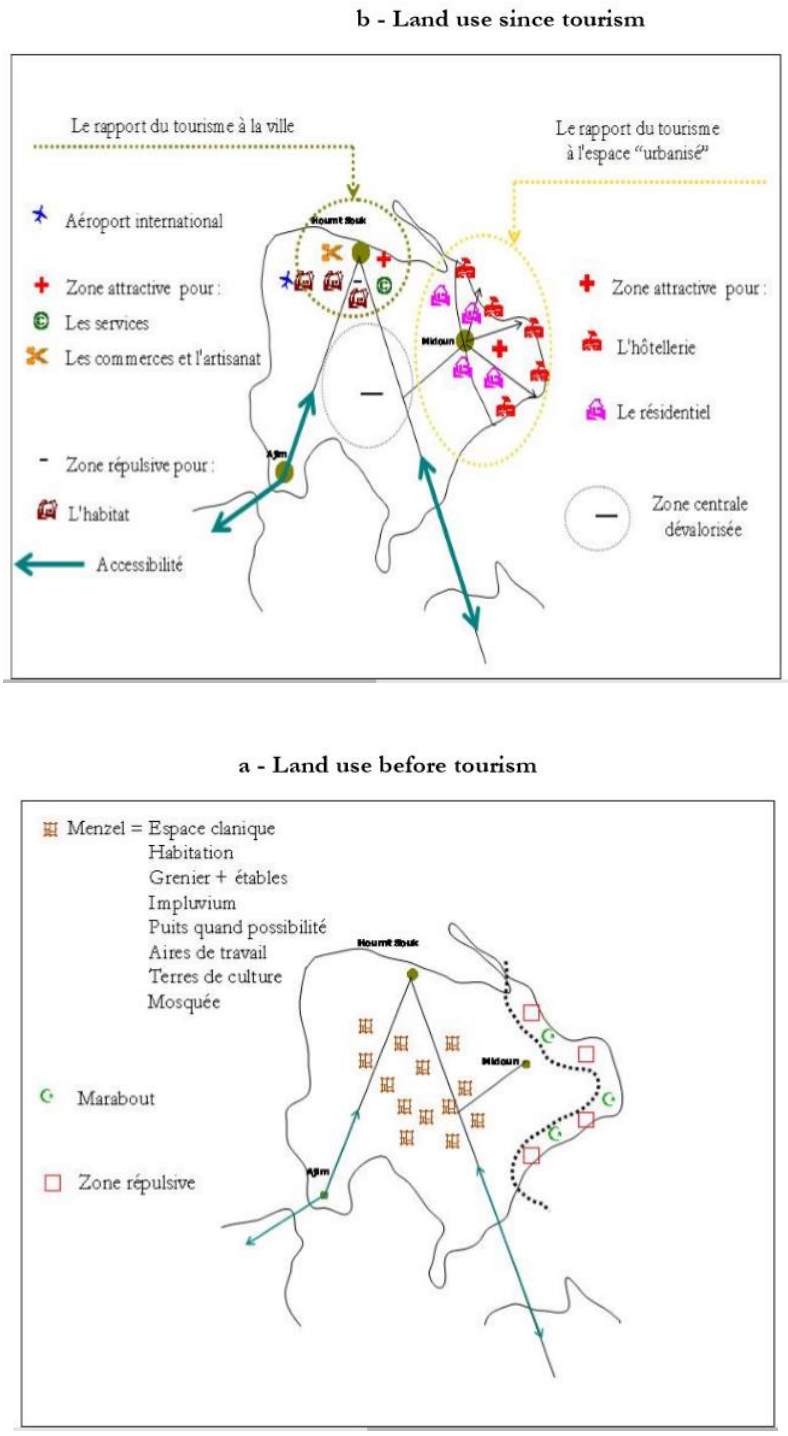

Figure 20. *The impact of tourism development on land use. (Source: Profile of Sustainability in some Mediterranean Tourist Destinations- after Chapoutot, 2011)*

By 2015, 9.6% of Djerba's total coastline was urbanised, mainly for tourism development (ANPE, 2016). This is an increase of 1.1% from what it was in 2005 (ibid) and certainly much more of what it was in the 90s, when tourism development was intensified. Violations are decreasing in the 25m coastal zone, from 33 in 2012 to 23 in 2015 (ibid), but all violations contribute to coastal erosion. The fact that the Tunisian government is attentive to this issue demonstrates excellent foresight, often not found in other regions where coastal

tourism is a mainstay of the local economy. Coastal hotel developers face increasing climate risk, which will have growing impacts on tourism's facilities as super storms and sea level rise become the new normal. At a time when both institutional investors and civil society are raising serious questions about capital outlays in the face of climate change, the failure to account for climate-related risk leaves many hoteliers around the world vulnerable, and their workers even more so. (Epler Wood, Milstein, & Ahamed-Broadhurst, 2019)

The impacts of climate change on the coastal zone of Djerba are monitored by the Agency for the Protection of Coastal Development (APAL). According to the Agency's study on mapping the vulnerability of coastal areas (Etude Carte de vulnérabilité, APAL-IHE, 2012[20]):

- Djerba, with its islands and islets, has a total coast length of 223.16km, out of which only 55km (24.6%) are considered stable and not subject to erosion (mainly rocky and cliff coasts).
- Djerba has the longest sand coast of the Tunisian islands, at 52km (23.3% of total coastal length), equal to 76% of total sand coast and the most important dune system of the Tunisian islands.
- Generally, there is a substantial lack of measurements and studies that explore the impacts of sea level rise (SLR) on coastal areas in all Tunisian islands and in Djerba in particular- In Djerba, only 4.45km of coastal area have been explored– that is, approximately 2% of the island's total coastal length.
    - That said, current estimates suggest that SLR threatens approximately 5932ha, with submersion of 11% of the total island area. The most pronounced impacts of such potential submersion will be in the north and north-east region, which is the most urbanised (Figures 21, 24).
- Approximately 53% of sand coast in Djerba is under threat from erosion, mainly in the tourist zone.

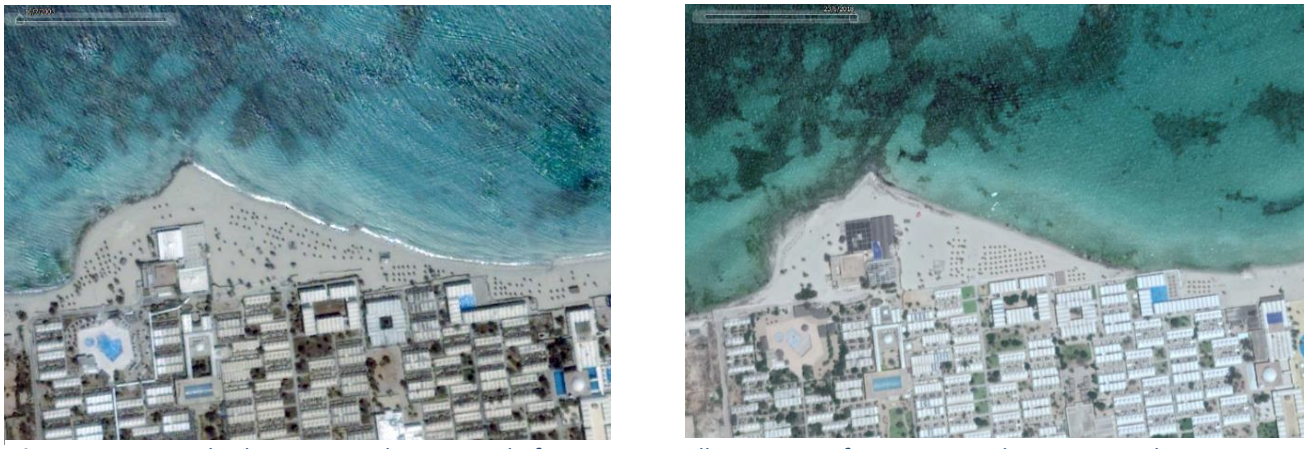

Figure 21. *Coastal submersion within a period of 15 years. Satellite images of an accommodation unit in the tourism zone: July 10, 2003 (left) ; June 23, 2018 (right). (Source: Google Earth)*

The elimination of dunes due to coastal development for tourist accommodation facilities has left the coastal waterfront unprotected against tidal surges and SLR. Concrete barriers and urbanised coastal construction have prevented any possibility of recovering the sand taken by waves (Figure 22). About 17.3km of the

[20] Quoted in ANPE (2016)

coastline in the tourism zone is vulnerable to SLR, largely due to these waterfront construction patterns (Figure 24).

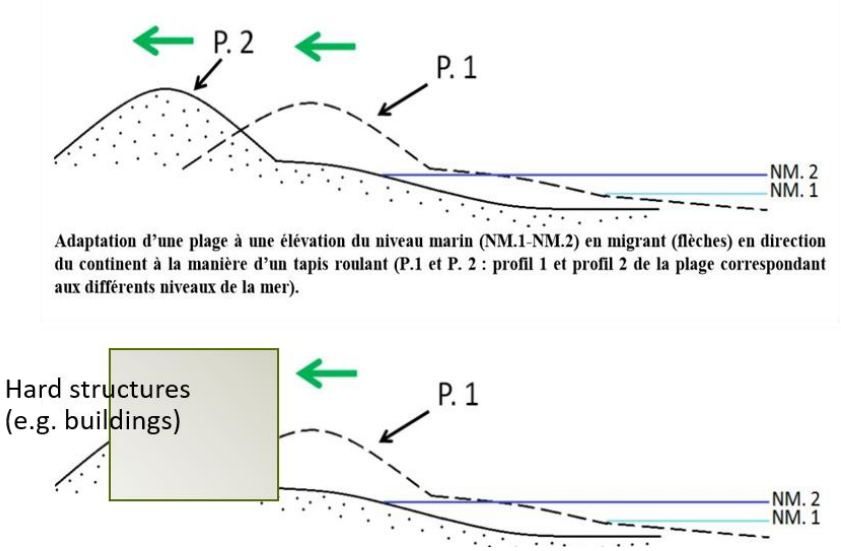

Figure 22. *The impact of hard structures and the elimination of dunes on the coastal front. Intact dunes have the ability to migrate towards the continental area and recharge the coast with sand that is taken by waves (upper sketch). Elimination of dunes with hard structures cancels this natural process (Source : Adapted by the authors from the 'Etude sur la gestion durable des systèmes insulaires de la Tunisie'* (ANPE, 2016)*)*

APAL is working on assessments and projects to address coastal erosion and submersion. Currently, projects have been implemented on the north-east coast of Djerba and there is ongoing work along 7km in Aghir. The main challenges APAL faces relate to the high costs of protection works and lack of overall response strategy to identify priority areas (APAL, n/a). Figure 23 shows one of the methods implemented by APAL to restore dunes in the coastal front in Djerba with rows of wooden sticks/trunks that contribute in wind speed reduction and the entrapment of sand particles – a cumulative process that restores dunes and dune flora. It should be noted, though, that the ability of these structures to respond to climatic impacts is limited (APAL, 2015). In addition, the construction of some esplanades and open spaces contributes to the protection of coastal areas, but these remain limited.

Figure 23. *Restoration of dunes in Djerba. (Source: APAL Document : 'Des paysages côtiers de la Tunisie Beautés, vulnérabilités')*

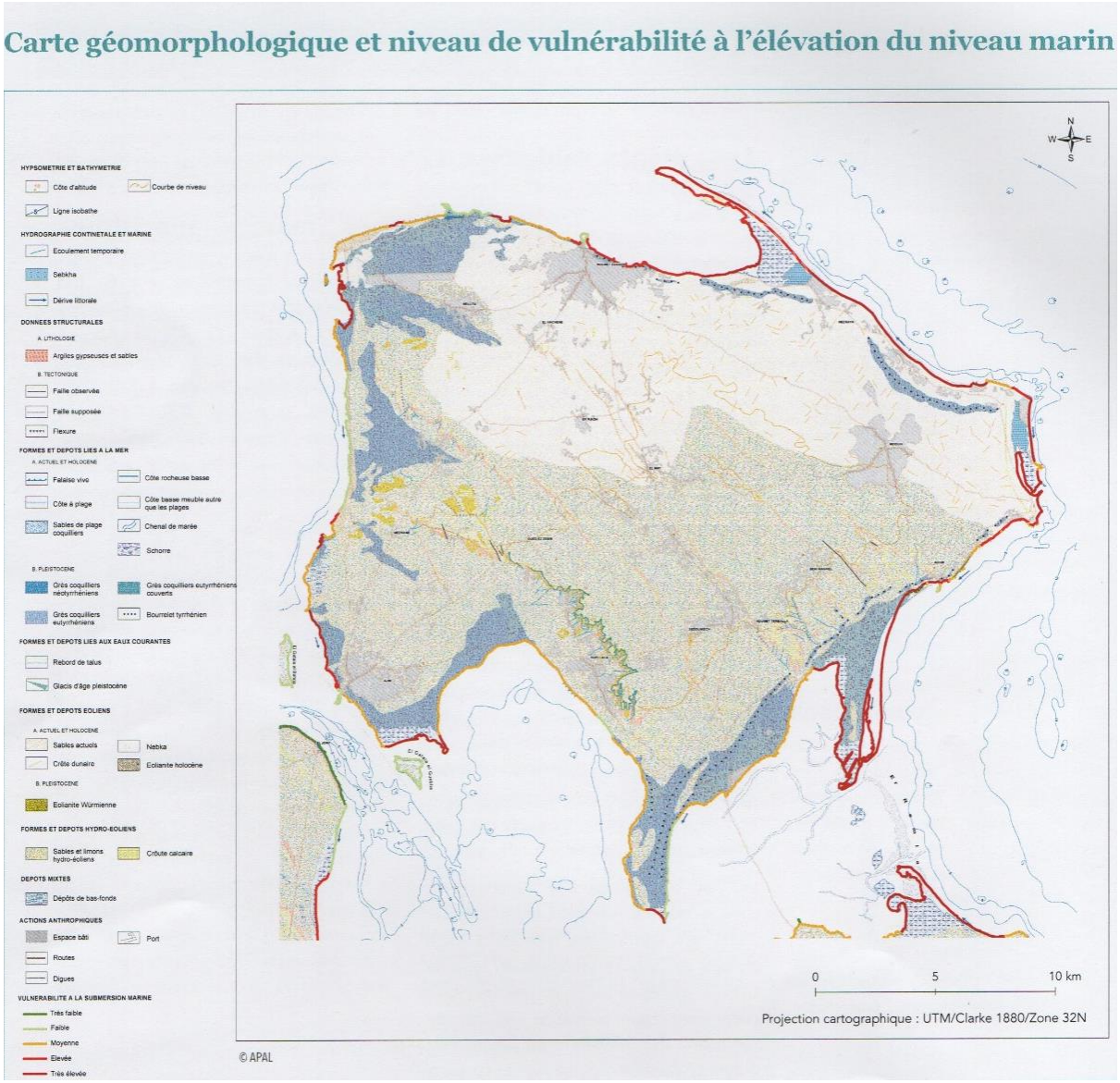

Figure 24. *Map of vulnerability to SLR of Djerba. Red lines indicate increased vulnerability to coastal submersion (Source: APAL). Note that almost all the coastline of the tourism zone is marked with red.*

Biodiversity[21]

Although there are a number of environmental NGOs and associations working in the area, environmental monitoring in relation to conservation issues remains very insufficient in Djerba (ANPE, 2016). Djerba has important biodiversity areas, such as the wetlands colonized by a large species of Mediterranean clam called *Pinna nobilis* and frequented by pink flamingos, the relic zones of Posedonia meadows, and the large dormitories of grey cranes (ibid). Three Ramsar sites have been designated – the Bin El Ouedian, the Guellala, and the Ras R'mal[22] – but the monitoring of these areas is rather inadequate. Indeed, it has been reported that the number of sea turtles nesting at the Ras R'mal has been reduced significantly due to tourism activities, such as recreational activities with quads and boats, and numerous sea turtles have died by eating plastic bags

[21] ISTI Framework indicators BIO 01, 02, 04
[22] APAL (website), Chifres clés 2015

thrown away in the sea[23]. The lack of financing to update previous biodiversity assessments and species inventories (some of which are more than fifteen years old) was pointed out as the major impediment for developing conservation and restoration projects and campaigns[24].

Carbon Emissions

Research on tourism demand for energy at the destination level, and its percentage of responsibility for national Greenhouse Gas (GHG) emissions, was one of the primary goals of the research program in Tunisia. Average per tourist night carbon emissions in Djerba were estimated at 25kgCO2e in 2017. These GHG emissions include all-important tourism-related direct emissions occurring within the destination (Scope 1),[25] plus GhG emissions resulting from power generation that serves tourism electricity demand (Scope2). Appendix 3 presents the carbon assessment and emission factors used. Total carbon emissions from tourism in Djerba were estimated at 100,330tCO2e per year.[26] Electricity is the highest contributor, followed by LPG and tourist transport with taxis within the destination, and further by solid waste, wastewater, water desalination, and aircraft taxiing emissions (Figure 25).

The per tourist night carbon emissions rate is more than three times higher than per day, per capita emissions in Tunisia (equal to 7,69 kgCO2e)[27]. This implies that if tourism in Djerba continues as usual, it will fail to follow the decarbonisation path that Tunisia has committed to with its NDC (41% reduction in carbon intensity by 2030). Moreover, our electricity regression model has shown that electricity use, the main contributor to tourism's carbon footprint, will increase significantly with increasing temperatures. Figure 25 shows the hotspots in terms of tourism carbon emissions that should be the focus areas for the decarbonisation of the sector.

[23] Interview of Harvard researchers at the Association for the Protection of the Island of Djerba (Association pour la sauvegarde de l' île de Djerba).
[24] Ibid
[25] Some tourist recreational activities were excluded from the assessment (e.g. sports activities) as these were not considered to have a significant impact on the overall emissions.
[26] For reference, direct emissions in Tunisia in 2010 have been estimated 32 356,6GtCO2e.
[27] Normalised annual emissions per day and per capita (population in Tunisia: 11,53 million).

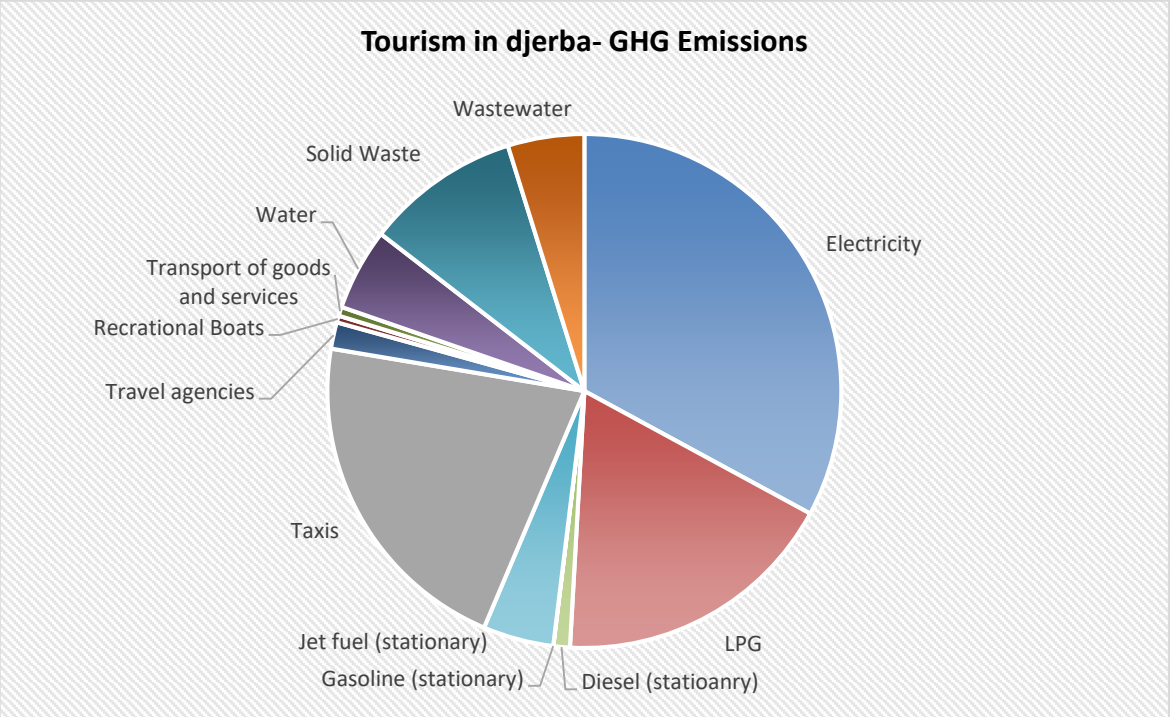

Figure 25. *The estimated carbon footprint of tourism in Djerba*

Tozeur

Tourism in Tozeur

Presently, tourism in the city of Tozeur represents a small segment of the city's economy (Table 1) and is characterised by stays of short duration that average 1.6 days per stay from 2007 to 2017 (Figure 1). Most tourists visit Tozeur as a 'break' from their stay in some other Tunisian tourist resort area, such as Sousse or Djerba. This not only minimises the economic benefit to the local community, but it also creates important implications for hotels that cannot develop economies of scale and optimise economic output per unit of resources consumed (e.g. energy, water).

Tourism was developed in Tozeur during the late 1980s, after the government established the delineated tourism zone at the west part of the city and provided subsidies for tourism infrastructure. After a period of rapid tourism growth, the area has been facing a tourism decline lasting more than a decade now. There are multiple reasons that contributed to this decline, ranging from structural and market to political ones. According to local stakeholders the development of Saharan tourism during the late 80s was mainly a centralized policy in which local actors (economic operators, municipality, NGOs, etc.) were not engaged. This prevented the use of local knowledge to contribute to the development of a sustainable tourism in the region[28]. As a result of the lack of holistic planning, local cultural and natural assets and resources have not been properly valued and this was an impediment for sustainable tourism development in the city.

[28] Interview of Harvard researchers with Nabil Gasmi, July 2017

Furthermore, the downturn in tourism numbers has been harsher than in Djerba (Figure. 2), likely due to the longer duration of security restrictions imposed on the area right after the Tunisian revolution in 2011.

At present, in the effort to revive Tozeur's tourism sector, there appears to be a discrepancy between the increased focus given to providing more upscale accommodation and improving the environmental (as explained in the next sections) and cultural physical assets of the destination. For example, although some efforts have been made to restore and revive Tozeur's unique architectural identity (e.g. using traditional bricks of solid clay in the construction and decoration of facades), these remain limited and thus fail to support an autonomous tourism economy for the city (i.e. where tourists stay to discover and enjoy the city, instead of just passing by).

Table1

Tourism in Tozeur: Baseline figures (2017)	
Resident population (in 2014):	37,370 (in 2014)
Tourist arrivals:	146,652
Total beds in operation:	2513
Tourist nights:	216,572
Population equivalent of tourism*:	1.6% (equiv. to 593 residents)

**The population equivalent of tourism is the ratio of tourist nights to residents' nights over a year*

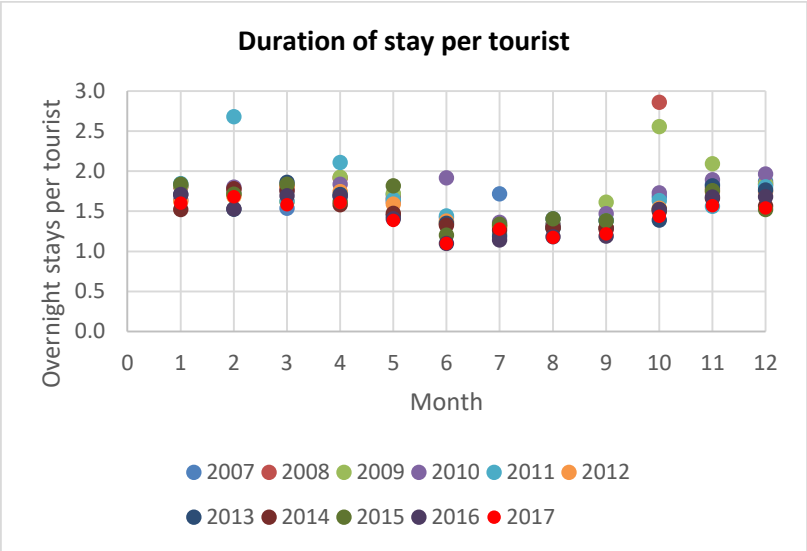

Figure 1. *Graph indicating the average duration stay by tourists (Source: ONT)*

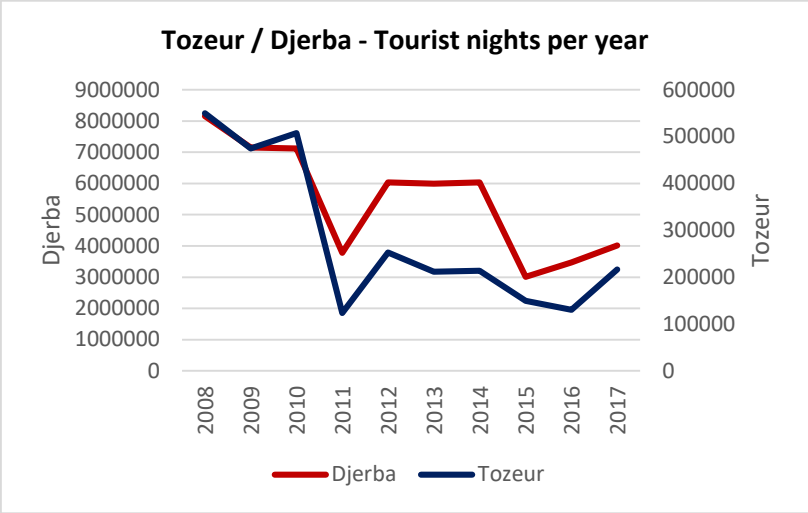

Figure 2. *Comparison of tourist nights per year in Djerba and in Tozeur*

Data Analysis and Results

The Tourism-Oasis-Water nexus in Tozeur

According to the Koppen-Geiger climate classification, Tozeur has a hot desert climate (BWh) and faces high levels of aridity with annual precipitation that does not exceed 80-100mm. Following interviews with local agencies and stakeholders during the ISTI project, and a subsequent review of reports and data, we distinguish two natural assets/resources as having a special link with tourism activity in Tozeur: the oasis system[29] and the endemic freshwater resources.

Oases and the unique geomorphology of Tozeur's surrounding areas are among the main assets for attracting tourists. Traditional agricultural practices in the oases contain a cultural component that is very significant for oasis tourism (Zekri et al., 2011). Oases have significant value for tourists and are being developed throughout the region. They can be valued for the amenities they provide to tourists, namely the economic benefit at the destination resulting from the existence of the oasis as an attraction (Figure 3 of Chebika oasis in Tunisia, near Tozuer, which is being funded by the World Bank for redevelopment as a tourism attraction). Indeed, in an oasis in Oman, this value has been estimated at US$

Figure 3. *The Oasis of Chebika near Tozeur*

[29]Oases in Tozeur support a three-level culture with the tall and resistant date palm trees providing shade and protection to underlying fruit trees that in turn provide shade to ground-level vegetable cultures

104.74 per tourist (ibid). Sustaining tourism activity in Tozeur is connected with sustaining land cultivation and ecosystem well-being in the oasis.

Tozeur's old oasis is considered one of the most significant oases worldwide. It has been sustained for centuries thanks to a traditional system of open canal irrigation that supplies freshwater from natural springs throughout the oasis, which supported the well-being of a unique ecosystem and the food self-sufficiency of the local community (Figure 4). The old oasis is degrading due to multiple factors, such as illicit urbanisation and the introduction of date monoculture plantations which remove the biodiversity of the ancient sites (CDCGE, 2016). While these plantations produce higher economic benefits, the palms have less resistance to disease and climate impacts. Land degradation has been further aggravated by the move of young workers from land cultivation to the tourism sector when tourism development started to flourish in Tozeur.[30]

Figure 4. *Traditional irrigation system, central oasis, Tozeur*

At the same time, and around the period that tourism was introduced to Tozeur, the implementation of a government project to tap the confined aquifer with deep artesian/pumping wells took place. The need for such an intervention was largely a consequence of the extension of the traditional canal irrigation system to provide water for the new oases that were being developed around Tozeur to expand the old oasis[31] (Figure 5). The extension of the traditional canal irrigation system, which had been an adequate water resource for the old oasis for more than six centuries, led to the depletion of endemic natural spring water resources.[32] At that time, the exploitation of deep fossil water through artesian/pumping wells and a whole new pipeline network provided large quantities of water to supply both the agricultural and the tourism sector. In the absence of water management policies and awareness campaigns, this created the perception of water abundance among locals, leading to a behavioural change against water conservation (Dłuzewska, 2008).

[30]Interview conducted by Harvard researchers at the Center on Research for the Oasis, Tozeur on 05/17/2018.
[31] According to data provided by the CRDA (Commissariat Regional de Developement de l'Agriculture) of Tozeur, as of 2015, date palm oases covered a total area of 3,837ha (949ha old oases and 2888ha modern oases), and counted 818,024 date trees (265,481 in old oases and 552,543 in modern oases).
[32]Interview conducted by Harvard researchers at the Center on Research for the Oasis, Tozeur on 05/17/2018.

Figure 5. *Change in Tozeur's surrounding oases area (dark areas on images) between 1984 (left) and 2016 (right).*

Based on the above discussion, any planning effort, including environmental assessments, for the tourism sector in Tozeur, needs to also consider the inherent value of the ancient oasis system and the agricultural sector which is supported by, the ancient oasis system. The policy research questions applied to Djerba were also applied to Tozeur and will be reviewed in summary in the conclusion for both Djerba and Tozeur. (See Conclusions)

Water resources in Tozeur

Freshwater in Tozeur is mainly extracted from deep fossil water reserves (confined aquifer). Some exploitation of the unconfined aquifer/water table (up to 50m) also takes place, but to a much lesser extent than in previous years, due to its higher salinity level. The two main deep aquifers that supply Tozeur with freshwater are the Complex Terminal and the Continental Intercalary (Figure 6). Drilling deeper means that more non-renewable resources are exploited, but also that the freshwater supply becomes more expensive, as a higher amount of energy is required for extraction.

According to data provided by Tozeur's Regional Commissariat for Agricultural Development (CRDA),[33] both of these reserves are characterised as non-renewable resources. Over-exploitation has resulted in the loss of *artesianisme*[34] due to a decrease in pressure, making pumping a necessity (Kraiem, 2015). Extracted water has a salinity level of 2-6g/l, which is unsuitable for direct potable use, but largely acceptable for the oasis' halomorphic soils and the type of agriculture developed there. The drilling depth has now reached 2680m. Drilling depth has been gradually increasing ever since exploitation began, because the maximum allowable withdrawal from a specific resource is restricted by quota allocated among Tunisia, Algeria, and Libya. Each time the quota is exceeded, drilling needs to go deeper to get water.[35]

[33] The Regional Commissariat for Agricultural Development (Commissariat Régional de Développement Agricole – CRDA) is responsible for the management of underground water resources.
[34] 'Artesianisme' describes water that flows naturally from underground to the surface when a well reaches a specific depth.
[35] Interview conducted by Harvard researchers at the Regional Agency for Agricultural Development (CRDA) in Tozeur on 29/11/2017

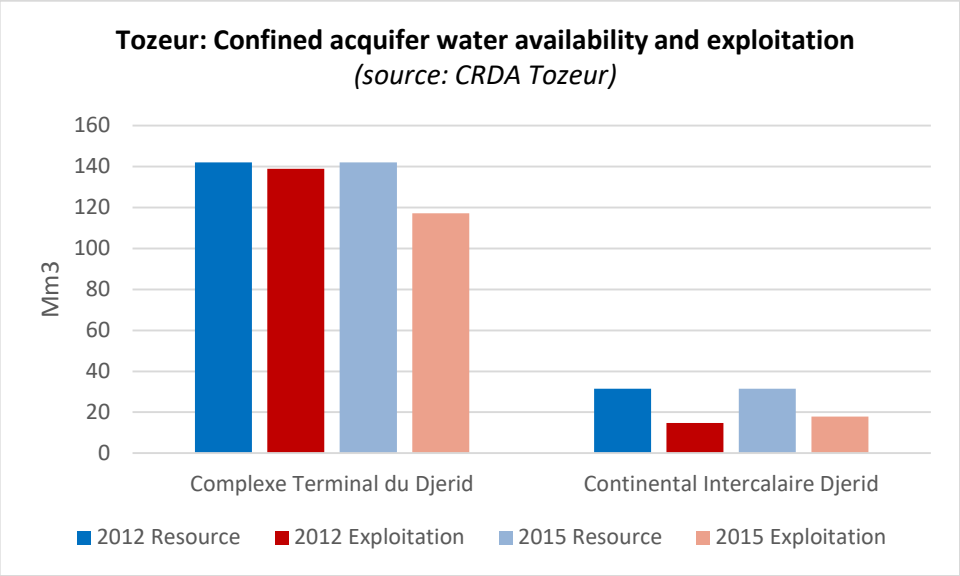

Figure 6. *Freshwater availability and withdrawal in Tozeur*

Agriculture is by far the main consumer of freshwater resources in Tozeur, with consumption of up to 92% of total water extraction (data from CRDA). The almost exclusive use of fossil water in agriculture has gradually enriched the water table with water that infiltrates from agricultural lands. As of 2017, there was an unexploited volume of 4 million m3 of water in the water table that could be exploited on an annual basis, if the right systems for desalination were in place. In fact, Tozeur's water table is replenished almost exclusively by this type of infiltration, given the low levels of rainfall that the area receives (Kraiem, 2015). According to the CRDA in Tozeur, this reserve, a once over-exploited resource, is now considered a partially untapped water resource. This is due to its high salinity level that in some areas reaches 8g/l, making it unsuitable for any direct use[36]. The non-exploitation of this resource, apart from perpetuating the unsustainable use of fossil freshwater reserves, may entail other risks as well. The rising of the water table level may result in further salinization of the oasis' already saline soils, rendering them unsuitable for cultivation and thus contributing to its degradation.

Tourism and water consumption

The International Tourism Partnership (ITP) published a new water risk analysis in 2018,[37] which reviewed *high* or *extremely high* current baseline water stress levels in destinations around the world for review by the hotel development community. Locations with high or extremely high hotel pipeline growth levels have a high risk of being impacted by future cost increases, according to the report. Such water risk calculations are now beginning to dictate where hotel investors can feasibly undertake tourism development without paying a premium for water that is not feasible for their corporations. While arid destinations may seek to provide inexpensive water, as has been the situation for Dubai for decades, these subsidies will begin to dry up if the

[36] Interview conducted by Harvard researchers at the Regional Commissariat for Agricultural Development (CRDA) in Tozeur on 29/11/2017.

[37] These locations are: Dubai, Hong Kong, Los Angeles, Manila, Melbourne, Mubai, Dehlhi, Sydney, and Surabaya, Indonesia. International Tourism Partnership, August 2018, ITP Destination Water Risk Index.

cost of producing water via desalination becomes too high. The focus of the policy research undertaken in Tozeur, separate from the situation in Djerba, was: can this region of high aridity manage water in a way that does not jeopardize local populations, tourism's long-term viability, or agriculture?

In Tozeur, these problems are small, but they will not remain so, as tourism is rebounding in Tunisia new developments are planned. the issue of private wells requires monitoring. According to data collected from SONEDE and the numbers of tourist nights provided by ONTT, average per tourist night freshwater consumption is estimated at 474lt. However, data provided by the CRDA show that in 2016 there were sixteen hotels in Tozeur that used private wells, with an estimated annual water withdrawal equal to 296352m3. This is roughly three times the total water consumption of tourism consumed by the SONEDE supply network (=102675m3). Hence, if water withdrawal from private wells is added per tourist night water consumption is 1842lt. Per tourist night water consumption is significantly higher than what it was found to be in Djerba, at roughly 2.4 times higher. This is likely due to:

- harsher climatic conditions in Tozeur than in Djerba that result in higher rates of evaporation (for pools and gardens)
- proximity of Tozeur to the desert, which results in dust accumulation requiring more water for cleaning
- lack of the right pricing for water extracted with private wells

The lack of the right pricing also becomes evident if one observes the relationship between water from the public utilities network (SONEDE) consumed by tourism and tourism's wastewater production. Figure 6 shows the paradox of having higher wastewater production in the tourism zone than the utilities water consumed by tourism. This results from the disproportionally high water use from private wells and creates important external costs, given that charges for wastewater treatment services of each tourism facility are based on a percentage of their SONEDE water bill.

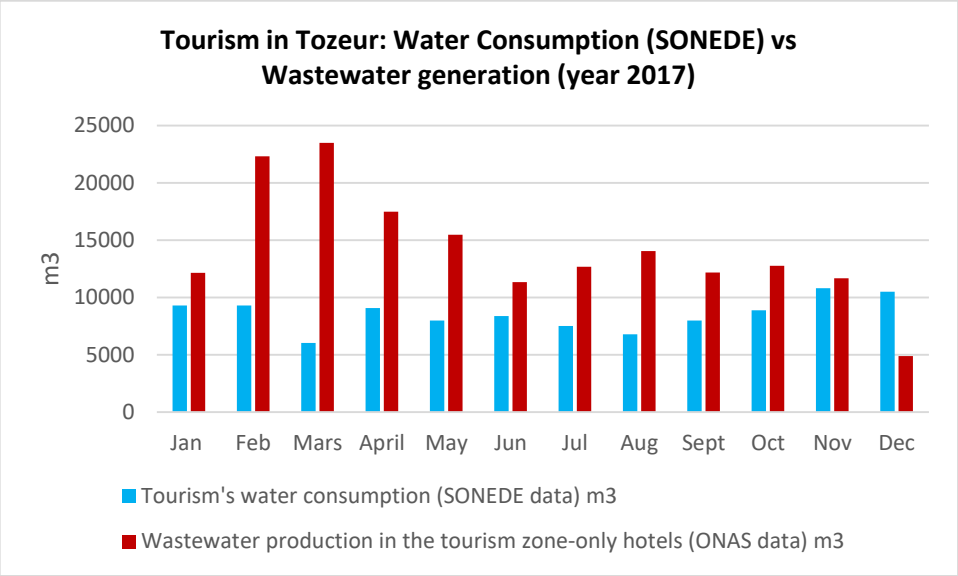

Figure 7. *Tourism's municipal water use and wastewater production in Tozeur*

In 2017, Tozeur saw an increase of 16% in tourist nights compared to 2016. As tourism numbers start to recover in Tozeur, water use in tourism establishments will increase as a result and the impact will be felt across the whole local economy. Water supplied to hotels by SONEDE comes from the Complex Terminal aquifer after going through desalination. The water that hotels extract with private wells comes from the same aquifer, though, as reported by the CRDA, many hotels have drilled deeper than what is allowed for private wells in order to get to reserves with lower salinity.[38] Under the Tourism-Oasis-Water nexus described here, tourism establishments could benefit from the cumulative water reserves of the water table through decentralised desalination units, which could contribute to the protection of the oasis by mitigating the salinization of their soils while, at the same time, providing some relief to fossil water reserves. With new large tourism developments now underway in Tozeur (Figure 8), it is projected that the tourism sector's water demand will increase significantly, therefore a holistic plan for water conservation urgently needs to be put in place. While the hotel community can assist by monitoring its own water consumption and implementing efficiency measures, the tourism community at large cannot stand apart from the larger water needs of local populations.

[38] Ibid

Figure 8. *Tozeur: A new luxury 5-star resort hotel development in the desert now under construction (left) to be in operation soon (right). [Source: Google Earth (left); Africanmanager.com (right)]*

Tourism and Energy demand

There are two major contributors to energy consumption by the tourism sector in Tozeur: 1) hotels, which use energy mainly in the form of electricity, and 2) tourist excursions with vehicles to the desert.

Tourism in Tozeur represents roughly 11% of the city's total electricity demand (Figure 9), a high percentage considering the population equivalent (see Table 1) of tourism in Tozeur equals only 1.6% of Tozeur's population. According to data provided by STEG and numbers of tourist nights provided by ONTT, average per tourist night electricity demand in Tozeur was 79KWh in 2017 and 129KWh in 2016[39]. This large fluctuation is likely affected by the number of tourist nights. When tourist nights increase, per tourist electricity demand decreases as a result of economies of scale (Figure 10). In all cases, however, per tourist electricity demand is significantly higher than in Djerba and this requires the attention of local actors. It also appears that the operational efficiency of tourism facilities has decreased, as shown by the comparison of numbers from 2017 with those of 2013 and 2014 (Figure 10). Although the number of tourist nights did not differ significantly among these years, average per tourist electricity demand increased from 64KWh in 2013 to 67KWh in 2014 to 79KWh in 2017.

[39] The per tourist night electricity demand estimation was based on the number of tourist nights provided by the ONTT for the respective years.

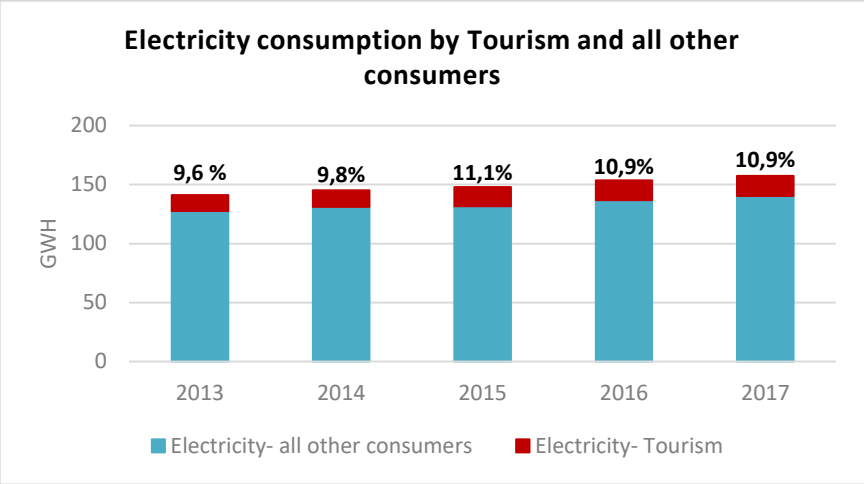

Figure 9. *Tourism's electricity demand in Tozeur (Source: STEG)*

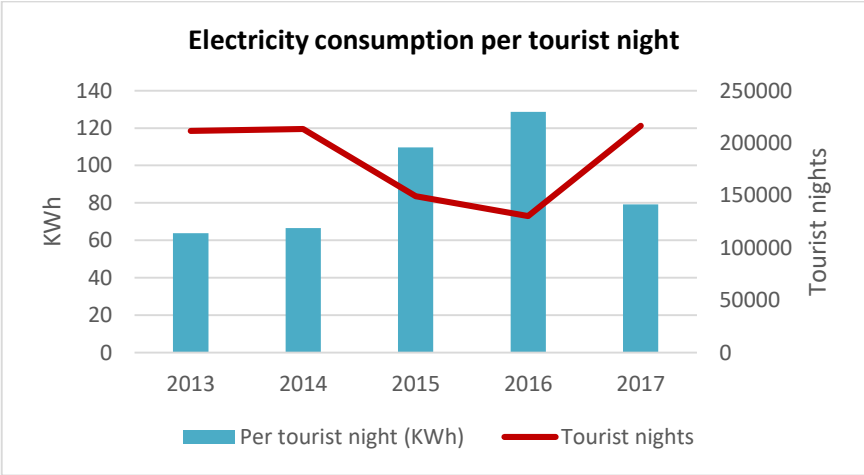

Figure 10. *Per tourist night electricity demand in Tozeur*

Desert excursions are one of the major tourist activities that the tourism sector in Tozeur has invested in, requiring the use of four-by-four diesel vehicles. Research on the energy consumption of these tourist excursions in the desert was based on interviews with travel agencies that offer this type of activity (Figure 11). Average per client diesel consumption was estimated at 4.1L per roundtrip desert excursion. The electricity equivalent of the diesel consumed per client per desert trip equals the average electricity use per tourist night in a three-star hotel in Djerba.[40] This leads to questions of how the sector can improve its energy productivity (i.e. the economic output per unit of energy consumed). Vehicles' higher energy efficiency and even electromobility, as well as an improvement of the ratio between the number of overnight stays to the number of desert trips, by means of a prolongation of the per tourist stay, must be in the focus of future decision making for the tourism sector in Tozeur.

[40] The calculation assumes a 3KWh power generation per litre of diesel.

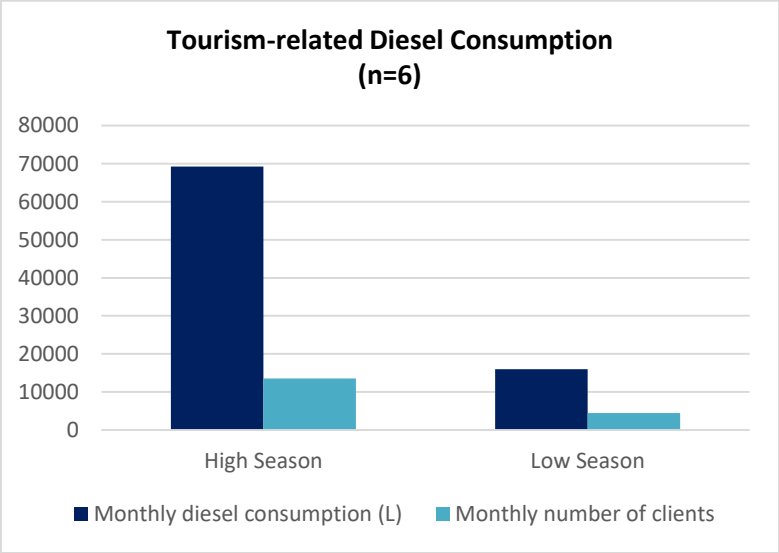

Figure 11. *Fuel consumption for tourism transport in Tozeur*

Beyond energy productivity, over-reliance on desert excursions for tourism in Tozeur might entail health impacts for the local community. It has been observed that the excursions through the desert generate dust in ways that are similar to desert storms that contribute to poor respiratory health. Airborne desert dust is one particle source with potential health effects that has recently been receiving special attention.

Desert dust is considered one of the biggest contributors to natural aerosols and particulate matter (PM) concentrations at regional scales well beyond the desert areas (Sandstrom & Forsberg, 2008; Querol et al., 1998; Colbeck & Lazaridis, 2010). The Sahara desert is the largest mineral dust source, producing about half of the annual mineral dust globally (Karanasiou et al., 2012). Saharan dust contains metals that induce oxidative stress as well as biological constituents (such as bacteria, fungi, endotoxins, and so on) that are implicated in various inflammatory responses; it may also be a carrier of anthropogenic pollutants (Erel et al., 2007; Rodriguez et al., 2011).

In morbidity studies, Saharan dust events have been associated with increased cardiovascular hospitalizations in Nicosia, Cyprus, and increased pediatric asthma emergency admissions in Athens, Greece (Middleton et al., 2008; Samoli et al., 2011). However, evidence from the literature regarding the possible lagged effects of these specific events is rather inconsistent. Although these desert dust outbreaks are natural, non-preventable events, the tourist excursions are not. A better understanding of the health effects that could be attributed to these excursions would provide much-needed guidance for decision making.

Impact of Climate change

Aridity, higher evaporation rates, an increase in thermal discomfort for humans and thermal stress for plants and animals, change in precipitation patterns, and land degradation are the most significant impacts that climate change entails for Tozeur. Climate simulations show a continuous expansion of aridity from south towards the north (Institut National de la Météorologie, n/a). The tourism sector will be affected by these

impacts, either directly due, for instance, to diminishing water resources and increasing costs for water supply, or indirectly due to the degradation of the oasis, one of the main attractions for tourists in Tozeur.

The more detailed data acquired in Djerba allowed an analysis on the projected impact of climate change on electricity and water demand by the tourism sector. Although the data acquired in Tozeur did not allow the same level of analysis, the correlation is applicable to Tozeur as well. In fact, given the average temperature increase observed in Tozeur (Figure 12), which has been recorded at more than double the global average, the impacts of climate change in Tozeur might be even more pronounced than in Djerba.

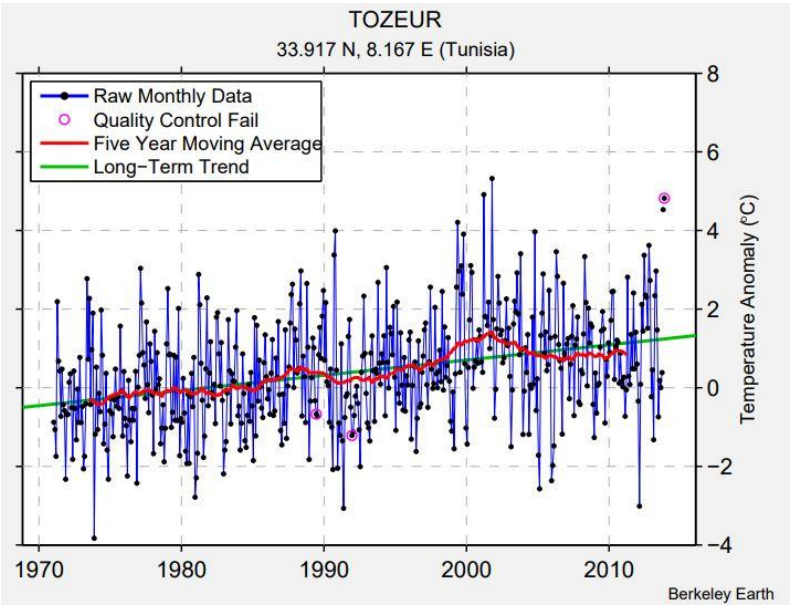

Figure 12. *Temperature Anomaly in Tozeur from 1970 to 2015 (Source: Bekeley Earth)*

Limitations of the data analysis in Djerba and Tozeur and opportunities for future research

Most of the data analysis results presented in this report were based on data collected from local utilities (e.g. STEG, SONEDE, ONAS), national/local agencies (e.g. ONTT, CRDA), municipalities, and the private sector. The analysis assumed full credibility of the data received. The level of confidence in data analysis results depends on the completeness of the data received for each category area. In cases where data gaps were covered with extrapolations and other assumptions, the level of confidence is medium to low (see Appendix 2 for an estimation of the level of confidence for each of the data categories). In all cases, an effort was made to maximise the elaboration of the data acquired and research outcomes. Future research by means of a replication of the ISTI Framework needs to review areas of data incompleteness that led to low/medium confidence in the present analysis and foster improvements in these areas.

Policy Analysis of Tunisia's Capacity to Monitor Tourism Impacts

Policy analysis was undertaken in Tunisia to determine how the growth of tourism can be understood as part of the nation's larger policy goals to preserve the environment and lower greenhouse gas emissions. The policy research questions were: what policy pathways will enable Tunisia to use tourism impact data 1) to provide a science-based set of measures for national NDC reporting, and 2) to provide a set of local, precise measures of the unaccounted for demands that tourism growth places on local resources and utilities, including water, wastewater, energy, solid waste, and land-use. Policy research was performed via interviews with policy makers in Tunisia in July 2018. Interviewees are found in Appendix 5. Tunisia is increasingly aware of its vulnerability to climate change impacts, has been very active in climate policy circles, and was among the first countries to ratify the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol.

NATIONAL STRATEGIES AND PLANS

- **United Nations Framework Convention on Climate Change** (2015)
- **National Water Code (Code Des EAUX)** (1975)
- **The 11th five-year Plan for Agricultural Policy** (2014-2015)
- **Economic and Social Development Strategy** (2012-2016)
- **TUNISIA 2020** (2016)
- **Climate Clause under Article 45 in 2014 Constitution** (2014)

The Ministry of Environment adopted several plans to address climate change impacts. It has participated in the Organization for Economic Co-operation and Development (OECD) Program for International Student Assessments, with the goal of promoting environmental education through curriculum and clubs in schools. The Government of Tunisia has also worked with organizations such as FAO, the World Bank, and the United Nations to conduct analyses of Tunisia's climate as well as to identify adaptation measures and objectives to reduce its carbon footprint.

The 2012 National Strategy on Climate Change has not yet been adopted as politically binding, but serves as a guideline for the country's efforts in implementing climate change adaptation and mitigation policies. **In terms of adaptation strategies,** Tunisia is currently improving its water management system and has incorporated climate change measures into its forest management guidelines. Others include the strategy on the adaptation of agriculture and ecosystems to climate change (January 2007), the strategy on the adaptation of coastal zones to climate change (February 2008), and the strategy on the adaptation of the public health sector to climate change (2010). Tunisia has also signed on to the OECD Declaration on Green Growth and has been actively engaged in the Green Growth strategy development following Rio+20 and in low-carbon and climate-resilient development activities showcased at the climate negotiations in Doha**. In the field of climate change**

mitigation, Tunisia has developed NAMAs[41] focused on energy, agriculture, cement, and wastewater, and has been an active participant in the Clean Development Mechanism (CDM).[42] The current NAMAs include: the cement sector NAMA, the building sector NAMA, the sanitation (wastewater treatment) sector NAMA, NAMA Support for the Tunisian Solar Plan (TSP), and The Agriculture, Land Use Change and Forestry NAMA.

Policy Research Outcomes

Tunisia's tourism policy has traditionally been led by the National Office of Tunisia Tourism (ONTT), which is the body that manages tourism demand under the Ministry of Tourism and Handicrafts. The ONTT does not have an environmental mandate per se, and therefore lacks the capacity to manage science-based data on the impacts of tourism growth. At the national level the Ministry of Environment oversees the management of science-based data on the different economic sectors, but there are no formal agreements relating to the management of the tourism sector between the Ministry of Environment and the ONTT.

Tourism is, without doubt, an effective tool for economic development, and despite the tourism downturn in Tunisia, it was roughly 6.9% of the total GDP in 2017 and was forecasted to rise by 4.2% in 2018. It attracts investment in infrastructure such as airports, hotels and local transportation. And it directly supports 225,000 jobs or 6.3% of total employment with a 4% rise forecasted for 2018 (WTTC 2018). Though less well understood, tourism also contributes to both national and local treasuries through a variety of taxes (both direct, such as taxes on aviation and accommodation, and indirect, such as VAT on sales), and businesses, and visitors pay to use local amenities and infrastructure (e.g. transport) (WTTC 2018). However, there is an inherent danger in underrepresenting or not representing the costs of tourism growth. Therefore, it is useful to understand the costs and benefits per tourist and the marginal cost as visitor numbers grow.

To understand the benefits of tourism growth, systems are required to calculate what tourism development costs local economies. These costs include the infrastructure required to transport, feed, and house; provide energy and water; and manage waste and waste water for the growing numbers of visitors and tourism workers in each destination. To come to an understanding of the issue of managing both costs and benefits, Tunisian policy makers discussed the following procedures via interview and a stakeholder workshop. In both private and public sessions leaders from the private, public, and civil society sectors discussed the possible need to:

1) **Undertake regular data collection and analysis** focused on and relevant to the local context
2) **Create a local decision-making policy framework** related to tourism and sustainability

[41] Nationally Appropriate Mitigation Actions (NAMAs) are part of the formal submission by parties declaring intent to mitigate greenhouse gas emissions in a manner commensurate with their capacity and in line with national development goals. https://unfccc.int/topics/mitigation/workstreams/nationally-appropriate-mitigation-actions
[42] Tunisia has been active in the global carbon market via its seven registered CDM projects and activities under the Kyoto Mechanisms.

3) **Bring together important tourism stakeholders**, e.g., Federations of Hotels and Travel Agents and the Tunisia Travel and Tourism Ministry (ONTT) to consult with experts on the efficient management of tourism
4) **Create a platform to access local, national, and international funding** for projects related to sustainable tourism

Policy Options for Establishing a Local Center for Research and Data on Tourism

During consultations with policy makers at the local and national levels, three policy options were considered to support current goals for preserving the environment and lowering climate change-related impacts.

- Policy Pathway Option 1 was a local government entity which would represent a joint intuitive between the Ministry of Environment and the National Office of Tunisia Tourism (ONTT) on Djerba.
- Policy Pathway Option 2 was a local data unit reporting to the Ministry of Environment to assist with national goals for mitigation, adaptation and capacity building for Djerba.
- Policy Pathway Option 3 was a local data unit to inform local policy makers and non-state actors (e.g. NGOs) and other local stakeholders to help formulate and advocate for improved policies at the local level for Djerba or Tozeur.

Djerba

The first option discussed was a local government entity that would represent a joint initiative between the Ministry of Environment and the National Office of Tunisia Tourism (ONTT) to provide local stakeholders with relevant data on environmental impact through feasibility studies and the provision of useful insights about the impact of tourism on resource consumption. It would be an integral part of the ONTT's planning processes (Figure 1).

To link national tourism policy to environmental policies, it would be necessary to involve the ONTT which operates with civil status and financial autonomy under the supervision of the Ministry of Tourism and is administered by a Governing Board and chaired by a Director General. It is structured in 16 regional offices in major tourist destinations in Tunisia and 19 international offices, with the main task of implementing Tunisia's tourism strategy. Its regional offices oversee the quality control of tourist infrastructure and the organization of local tourist events, fairs, and festivals. The international offices are responsible for the design and implementation of marketing and media campaigns for the tourist sector.

More specifically, the ONTT in Djerba-Zarzis has the following functions:

- develop the tourism sector
- regulate and control tourist activity
- promote the tourism product
- provide hotel and tourism training

The ONTT Medinine is the main governmental representative involved in the tourism sector in Djerba. This department is responsible for tourism supervision on Djerba Island as well as in four other municipalities in the governorate. Through a joint decision between the Ministry of Environment and ONTT national offices, a research and data center could be attached to the ONTT office in Djerba.

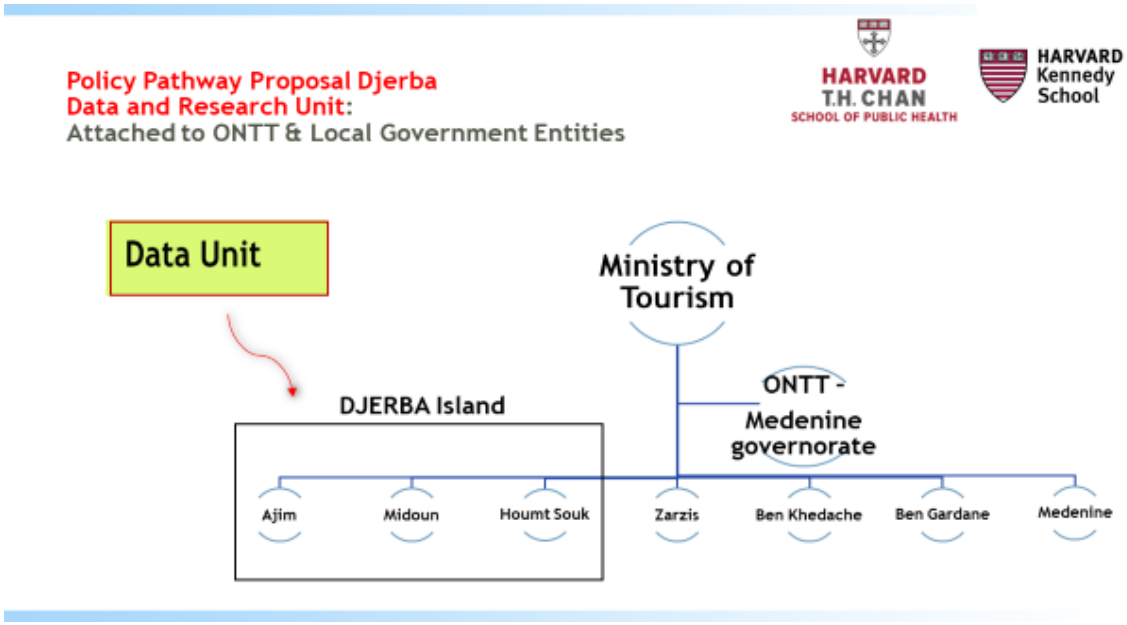

Figure 1

The unit would respond to the needs of the three municipalities in Djerba: Ajim, Midoun and Houmt Souk. One thing to note is the discrepancy between the size of the tourism industry in the three municipalities, with Midoun being the main tourist destination, as most resorts are located there. As the municipalities in Djerba island have different needs, the data unit would be located at the ONTT office, where high-level planning is conducted and where the data unit could better influence decision making. Lastly, and as mentioned above, municipalities do not currently have the capacity, organizational structure, or the needed capabilities to fully and solely absorb the data unit under its wing.

In theory, the research and data unit would not work in a vacuum. It is the municipality that needs the data and requires the expertise and financing to manage and improve its infrastructure. Representation from the different stakeholders would be part of its structure, allowing genuine participation and interchange. Ad-hoc as well as regular meetings (e.g quarterly) would allow stakeholders to discuss priorities, challenges, and needs (Figure 2).

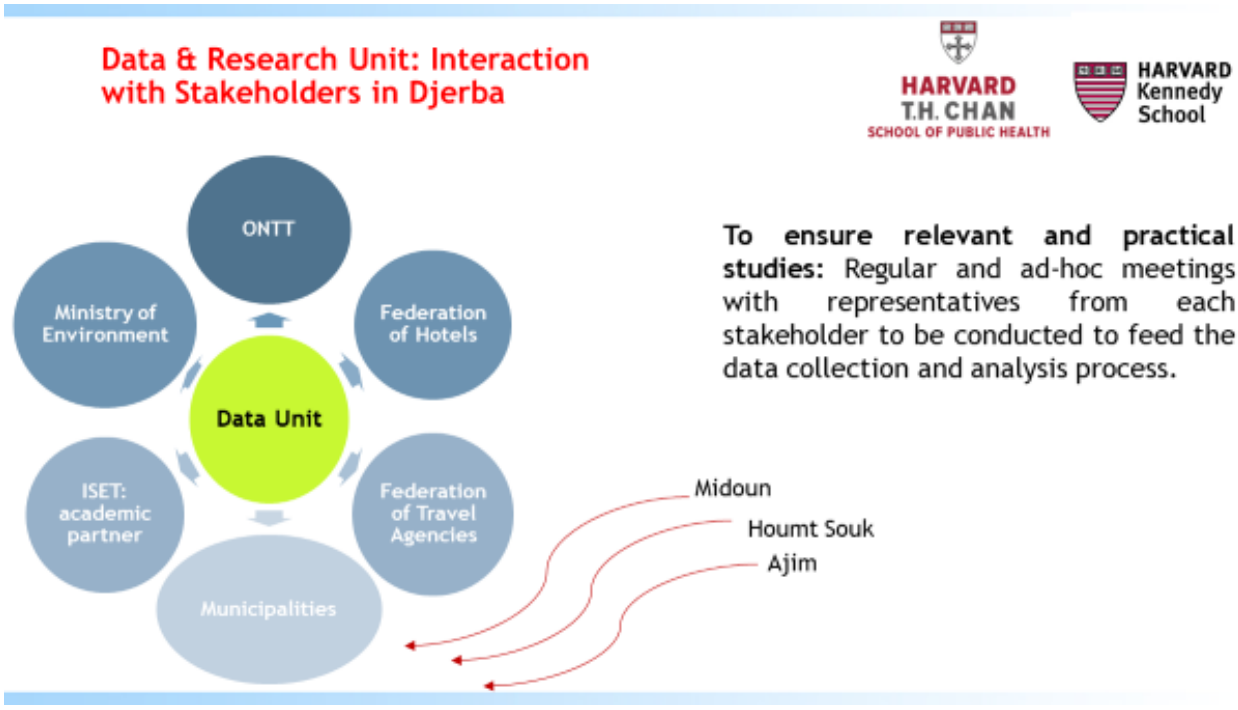

Figure 2

A second policy pathway explored was to deliver data from local tourism data units to the national Ministry of Environment, which is divided into three administrative bodies:

- Mitigation unit: a national working group that meets every month for consultation, preparation of the work plan, and making decisions around mitigation strategies.
- Adaptation unit: a national working group with a similar function around adaptation.
- Capacity building unit: provides training for international negotiation, finance, technology, data gathering & analysis, and general technical assistance (upon request, and as needed).

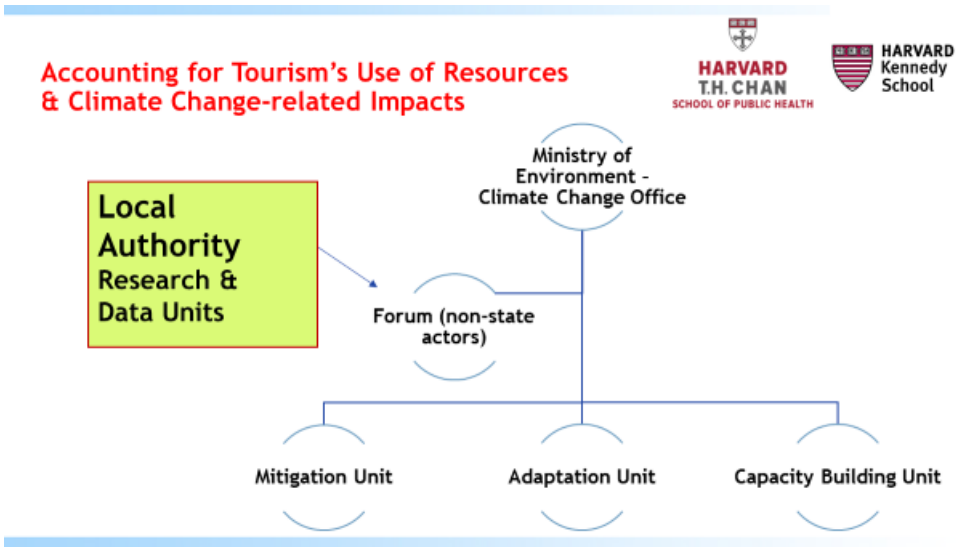

Figure 3

The local travel and tourism data/research units would coordinate with other non-state actors via a forum established by the Ministry of Environment, which would incorporate private sector actors, NGOs, and local authorities in meetings every month to discuss challenges, solutions, and projects. This structure would allow a platform for using the ISTI Framework for decision making at the national level. It would allow the travel and tourism data/research units to use this platform to provide data, communicate destination challenges, and help form policies (Figure 3).

Tozeur

Because Tozeur is not as robust a region for tourism development, a different set of policy pathways was explored. Given that Tozeur is the beneficiary of more regional development funding and grants, creating a non-profit that acts as a cooperative and provides analyses and studies for tourism planning was proposed as an option. In addition, there is only one municipality in Tozeur, which makes the policy landscape easier to navigate. During the municipal meeting in Tozeur, the municipality renamed their tourism committee the 'sustainable tourism' committee as a gesture to show their commitment to the initiative. The question is: how can their eagerness be translated into action?

In this case, a research and data unit would provide analyses for the municipality as an independent unit. It could cooperate with the Southern Development Council, the predominant research body in the region, and receive a variety of types of feedback from water, wastewater, electricity, and other directorates as part of its management duties. It would have a similar private sector relationship to that outlined in the Djerba model (Figure 4)

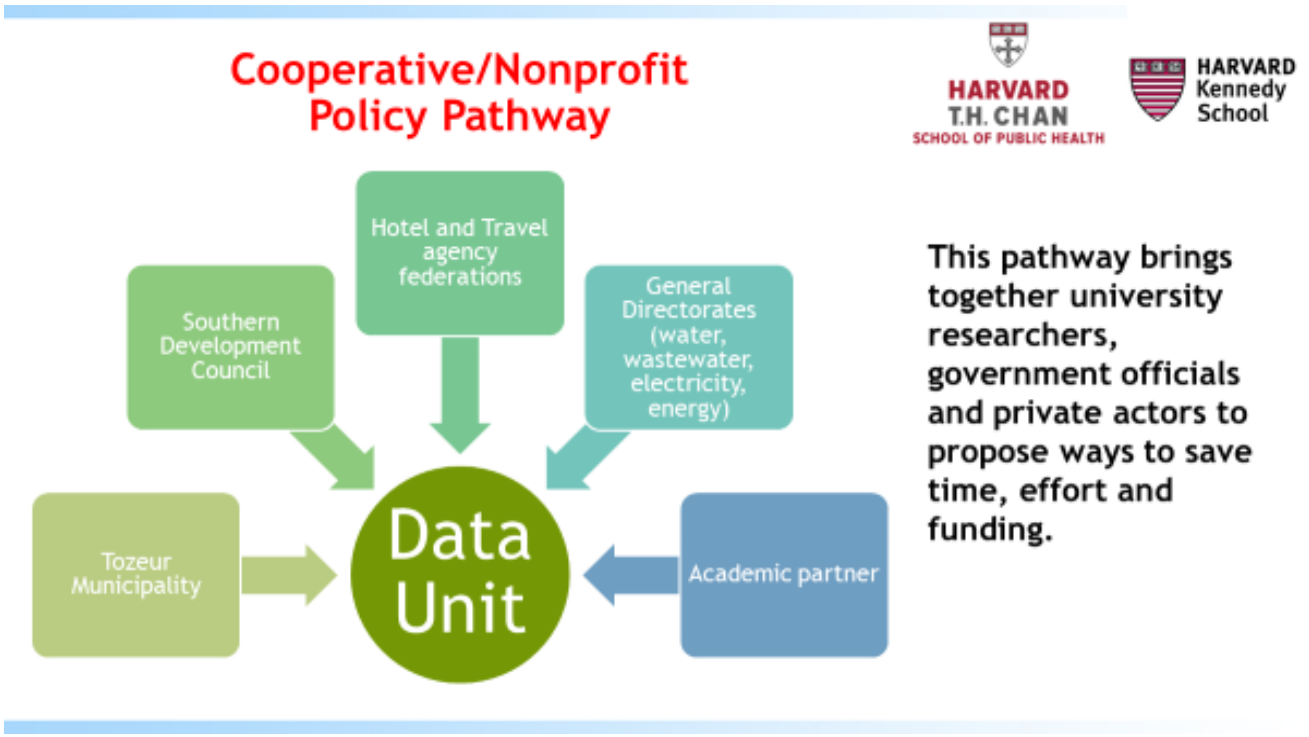

Figure 4

Funding for Research and Data Unit Establishment and Operations

To ensure the sustainability of a research and data unit, a mix of *local* funding sources would be required to establish the data unit and fund its ongoing operations. Municipalities do have an increasing number of revenue sources in Tunisia, due to the decentralization of government. But, no municipality has as yet analysed future revenues from tourism vs. costs. The concept of data units to track the utility costs per tourist is very new on a global level, but they would enable muncipalities to study how to lower costs for both business and government to ensure local well-being. With such data in hand they could advocate for more sensitive policies at the national level and could use the following sources of revenue:

1. **"Loan Fund and Support of Local Communities" (CPSCL):** public regional fund specifically allocated to local authorities on needs basis.

2. **Municipal budget allocations:** the Tunisian Council of Municipalities approved the draft budget for 2019 on October 29, 2018. There was a 12-percent increase in budget allocations to municipalities from the previous year. This is the result of the gradual transition of power from central government to local authorities.

3. **Tax reallocation:** the government can reallocate taxes accrued from tourists to further develop the sector and allocate a fund for supporting research and data analysis on sustainable tourism.

New opportunities to utilize:

- **Tunisia introduced a new tourism tax starting on October 1, 2018:** every tourist who comes to the country will be charged a departure tax of 30 dinars (about 13 euros).
- **New local tax will apply for stays in Tunisia starting from November 1, 2018 and is charged per person per night.** The amount for the tax will be two Tunisian dinars per night for three-star hotels and three Tunisian dinars per night for four- and five-star hotels, payable locally.

The policy pathway could be to create a timeline for the gradual transition of resources from the ad-hoc regional fund (such as CPSCL) to more sustainable resources such as the municipal budget or tax revenues. The proposed timeline is highlighted below (Figure 5).

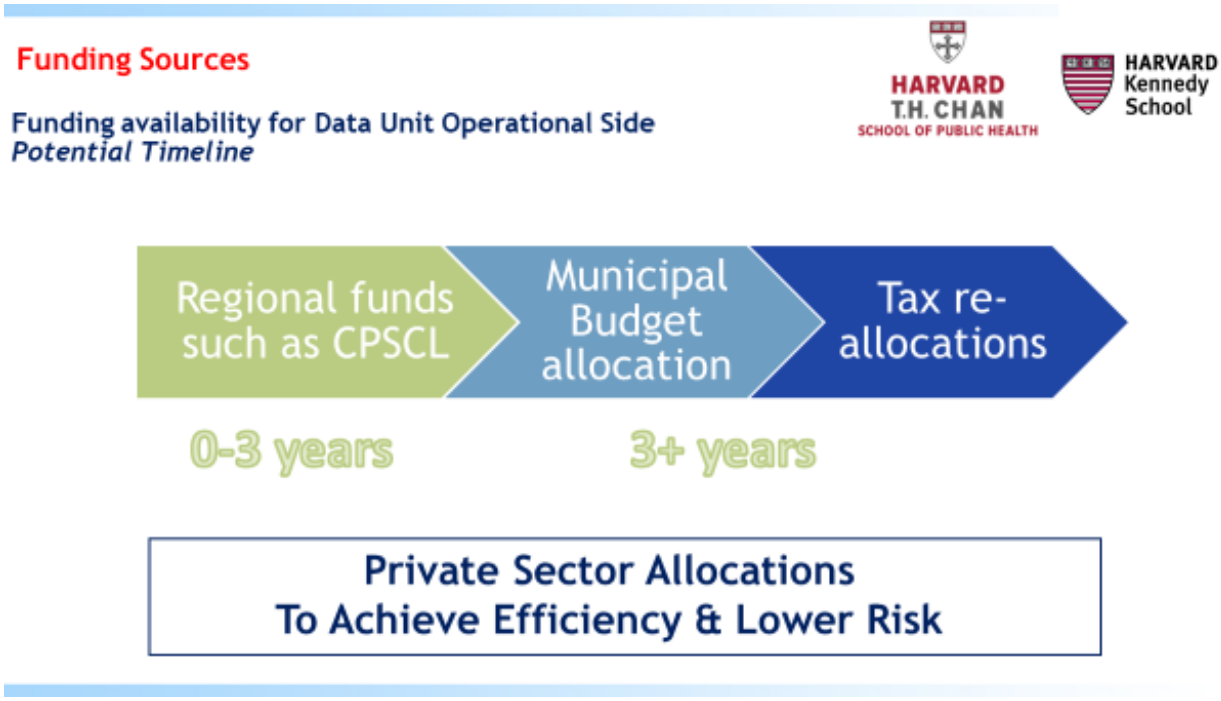

Figure 5

While climate financing was one of the primary opportunities for helping Tunisia attract funding to its key tourism destinations, it was found that there are barriers to obtaining climate change finance for lowering tourism vulnerability and GhG emissions in Tunisia:[43]

1. **Absence of focal sectoral point to combat climate change in government institutions** (i.e, tourism): the only entity in Tunisia that is affected by climate change and has a sectoral focal point is the Ministry of Agriculture. Tourism has not been recognized as a primary sector to consider for mitigation and adaptation action.

2. **Lack of accountability**: no MRV system in Tunisia for tourism exists

3. **Tourism's economic downturn:** the tourism economy is presently only 6.6% of Tunisian GDP and therefore is not considered to be a primary driver of GHG emissions within the economy of Tunisia at present.

Workshop Results

Two final workshops were held on Djerba Island on November 15 and 16, 2018 to review the data and policy results of the research program. The first workshop, on November 15, was held with representatives of the research community, primarily instructors with the Djerba Institut Supérieur des Etudes Technologiques (ISET). This was a half-day workshop to provide the project's local researchers with the data and governance results. The November 16 workshop was a full day workshop with 48 senior representatives from government,

[43] (Reseau Alternatif des Jeunes - Tunisie, 2018)

business, business associations, academia, and civil society. A list of participants for both events is found in Appendix 6.

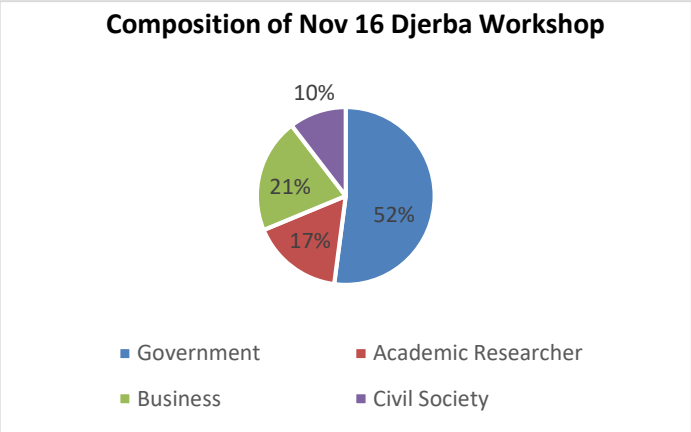

Figure 6 *Workshop Attendees, November 16, 2018*

Representation according to sector for the November 16 event is found in Figure 6 (48 attending, Appendix 7). This dialogue was balanced toward governmental representatives, but with strong representation from business leaders from both Djerba and Tozeur. The governor of Medenine spoke at the opening session, giving a statement on the importance of supporting the growth of tourism in the region while at the same time requiring a proper evaluation of local utilities costs needed to support growth.

The Mayor of Houmt Souk, the primary municipality and seat of local populations in the tourism region on Djerba Island, spoke on the importance of measuring the impacts and costs of tourism, in addition to reviewing its growth statistics. The head of environment for the national ONTT expressed his support for measuring environmental impacts, while stressing the importance of growth and bringing back Tunisia's tourism industry as a key component of the country's economy.

Djerba and Tozeur Roundtables

In the final roundtables, Tozeur and Djerba residents and stakeholders deliberated on the best policy pathways to use based on the results of the project. The policy pathways explored in this document were presented during the workshop to offer local stakeholders the results of the project's policy research while asking them to determine their own steps forward. The overall dialog at the Djerba roundtable looked at the following options:

- establishing an observatory for regional tourism data gathering
- establishing a fully representative group that involves all of the tourism federations, tourism guides, and the municipalities
- working under a pre-existing Conseil Regional du Tourisme, which has a legal framework and existing governance structure
- developing a plan for the observatory to be supervised by the Conseil Regional du Tourisme, whose president can coordinate with the Governate of Medenine
- creating a system where the observatory would transfer data results to a national council to manage tourism data

The mission of the observatory was discussed without being finalized. Civil society representatives felt that the observatory must play an important role in raising awareness of climate change impacts. Business and government representatives supported the concept of regular data collection, reinforced by a legal authority such a Conseil Regional to ensure that government utilities regularly update the observatory. They noted that the ONTT would not have this power and could not oblige the utilities to divulge data on tourism uses, while the Conseil Regional would have this legal power.

The Tozeur roundtable the mayor, who was in attendance, pointed out that the municipality has the legislative power to create sustainability projects. She supported the idea of creating a unit to gather data within the municipality that would have the legal power to acquire the data required from the utilities. It was noted that:

- by 2020 the municipalities will have their own budgets, which they can allocate in part for managing data on tourism impacts
- it is up to the municipalities to foster good practice in the management of energy, water, solid waste, and wastewater
- the municipality can organize events, generate ideas, and make all stakeholders aware of the importance of resource efficiency

It was noted in the Tozeur session that local stakeholder organizations could work with the mayor to create the proposals required to attract financial resources to a research/data center and ensure that tourism becomes more efficient in the use and management of local resources.

Final Workshop Conclusions

The workshop was concluded with reports by the stakeholder roundtables to the full workshop group. At that session, the Deputy Director of the Ministry of Environment, Mohamed Zmerli, who is Tunisia's official liaison for the management of Tunisia's NDC climate targets, suggested that the Ministry of Environment (MoE) could assist with the continuation of the project by supporting the replication of the ISTI Framework in Tozeur and Djerba in 2022, five years after the initial project in 2017-18. He suggested that the MoE could finance the project and work directly with the ISET researchers in Tozeur and Djerba to support the collection and analysis of data to ensure there is a follow-up report to regional and national authorities.

Three scenarios for ISET to manage data collection in 2022 were laid out by Djerba's ISET researcher on the project, Dr. Olfa Helali. The primary goal for ISET's work on replicating the ISTI Framework in 2022 would be to continue data tracking and reporting using the ISTI framework. The base goals for Scenario 1 at 10,941 USD are 1) to ensure that ISTI Framework data is collected using the same research approach, 2) that students from ISET work on the project, and 3) that strategies for sustainable tourism are discussed with public and private entities in 2022 based on the data results from 2022. The additional goals, which can be achieved in Scenario 2 for 17,924 USD, are to establish a permanent data gathering software system with automated systems

connected to local utilities. And in Scenario 3 for 43,911 USD, such automated systems would be directly connected to municipal and national planning bodies and be reported to local stakeholders via participatory planning techniques. See Table 2 below.[44]

Primary Goal for Djerba Tourism Research Data Center	**Scenario #1 Goals** **Base Goals for Project**	**Scenario # 2 Additional Goals**	**Scenario #3 Additional Goals**
Continue data tracking & reporting using ISTI Framework in Djerba via ISET	Analyze tourism use of resources, GhG emissions and cost to manage tourism for public private entities	Set up and implement data management software	Connect data unit to local public and private agencies
	Report data on a monthly basis and summarize on an annual basis	Establish automated systems with utilities for data reporting	Use automated data gathering solutions to report directly to agency planners via data links
	Allow students to work on the project connected to local needs and		Orient ISET goals towards training of students to manage data gathering systems
	Help Djerba prepare its transition to green energy & resource management pathways		Involve local community and stakeholders in research results and stimulate dialog with local civil society
	Recommend and follow up on strategies for sustainable tourism with public and private entities		
Budget	**$10,941**	**$17,924**	**$43,911**

***Table 2**. Scenarios for ISET Managed Tourism Research Data Center, Djerba, Tunisia*

Conclusion

The *Tourism and Environmental Health in a Changing Climate* research project in Tunisia tested the ISTI Framework with two primary goals: 1) provide a science-based set of measures that can contribute to national NDC reporting, and 2) provide a set of local, precise measures of the unaccounted for demands that tourism growth places on local resources and utilities, including water, wastewater, energy, solid waste, and land-use. In both cases, the research demonstrated that 1) without further monitoring at the destination level, tourism

[44] All budget estimates are based labour costs and the availability of researchers in 2018. Tunisian dinar conversion rate to USD in 2018 at time of this report was 0.34

will play an increasingly energy- and resource-intensive role that will not be consistent with Tunisia's NDC goals for the Paris agreement, and 2) tourism has many unmonitored impacts on local destinations that are not accounted for, and municipal leaders can use this information to guide the development of more sustainable, efficient economies and for meeting the SDG goals. The larger question also raised by this research was: can science-based data on the use of natural resources by the tourism industry help Tunisia protect the assets that tourism depends on?

For each specific area explored in this document, there are important policy implications for both national and local decision makers. These implications relate to both the Paris Agreement and the Sustainable Development Goals.

1) Will the management of energy costs, and the accounting for those costs per tourist, allow decision makers to judge what steps are required to cover costs while transitioning to a greener economy, as part of their commitment to the Paris Agreement and the Sustainable Development Goals (SDGs)?

Per tourist night electricity demand had an annual average of 29KWh on Djerba island, Tunisia (average for the years 2016, 2017). This is significantly higher than previous estimates. Tourists in 2017 were the equivalent of 7% of the population on Djerba Island, but they were responsible for one-third of the island's total electricity demand. Tourist arrivals peak during July and August. These warm months of the year drive increased electricity demand for air-conditioning, which has important implications for power generation infrastructure that must cover peak demand. The warming of the climate will exacerbate current trends in peak power demand. Decision makers at the national and local levels need to evaluate how to improve energy resilience of their tourism economy by making all tourism facilities more efficient and considering island-wide strategies for renewable energy, especially solar energy where the island presents enormous potentials. It is therefore concluded that using the ISTI Framework to measure the energy demand at the destination level cannot only help to monitor the growth of GHG emissions for national tracking purposes, it can also contribute to developing local plans for meeting SDG goals as outlined in the monitoring section found in Appendix 1.

2) *Will the management of water availability, and accounting for those costs per tourist, allow decision makers to judge what steps are required to cover costs while transitioning to a greener economy, as part of their commitment to the Paris Agreement and the Sustainable Development Goals (SDGs)?*

Djerba is a water-stressed area with limited natural freshwater resources. In 2017, tourism was responsible for 25% of municipal water consumption. Per tourist night water consumption in tourist accommodations is higher than what has been reported for other Mediterranean destinations. A new desalination plant in Djerba treats seawater, which increases resilience of the island to water scarcity. , but requires energy with significant new costs per tourist. Average per tourist water consumption is roughly equivalent to a 20% increase in energy use per tourist per night, during the months of July and August. Furthermore, average temperature increases

due to global warming will drive water usage in Djerba up by approximately 6% by 2039. Such costs are presently not reflected in the charges tourists pay, and this should inform policy makers when considering the larger costs of producing water for tourists.

In Tozeur, water is a matter of survival. The city has one of the most significant oases in the world, which has been sustained for centuries thanks to a traditional open canal irrigation system. The expansion of the oasis and the subsequent tourism development has led to the over-exploitation of the key aquifers in Tozeur and drilling to support agriculture is going to increasing depths to obtain the required water resources. Tourism has very little to do with water scarcity at present, but in 2017 Tozeur saw an increase of 16% in tourist nights. Hotels primarily extract water using private wells – an unregulated practice that results in external costs for local utilities, especially wastewater treatment operations. There are synergies that can be developed between tourism and agriculture, and these go beyond the cultural component to include water management solutions that can alleviate the pressure on fossil water reserves. The significant new plan for a larger-scale high-end tourism development suggests that measuring and monitoring water demand by the tourism sector is increasingly required. Local authorities must foster water efficiency awareness campaigns throughout Tozeur's accommodation sector and apply the right pricing for the use of this valuable resource.

The analysis concludes that monitoring water use at the destination level can help to address national concerns and development programs for both agriculture and tourism. The management of water is of critical importance for Tunisia and will contribute to both the targets set out in the Paris Agreement and SDG goals. The ISTI Framework offers a useful tool for government to monitor its progress on managing water use for tourism (see Appendix 1 for measurement and monitoring indicators).

3) Will the management of solid waste, and accounting for those costs per tourist, allow decision makers to judge what steps are required to cover costs while transitioning to a greener economy, as part of their commitment to the Paris Agreement and the Sustainable Development Goals (SDGs)?

On Djerba Island there is presently no solution for integrated solid waste management. A previous controlled landfill site in Guellala operated until 2012, when it was closed due to complaints and protests from locals regarding the odour reaching their hometown. A 'temporary' bulking site was created to serve three municipalities until a permanent solution is found. In addition, the island still has a dozen untreated dumping sites. Tourism contributed 25% of the solid waste for Djerba in 2017. Previous assessments, referring to years with higher tourism numbers, had reported a significantly higher contribution of the tourism sector to solid waste generation, and this is likely to be the case as tourism numbers recover to pre-revolution figures. Efforts to lower solid waste have been made. Three companies collect recyclables in Djerba and export them to other cities on the mainland, but their activity is not adequate to recover all recyclables from hotels.
Unmanaged landfills have significant public health impacts due to the emission of gases such as benzene and carbon monoxide, but also because they form a breeding ground for biological hazards, including flies, rodents

and insects. which can cause a wide variety of diseases. On Djerba Island, residents within 2km of the bulking site are the most likely to be affected.

It is therefore abundantly clear that monitoring tourism's generation of solid waste as well as progress towards more sustainable solutions has important implications for Djerba Island and can contribute to better management at the local level while also providing strong evidence for national support for a waste management solution that will contribute to both the Paris Agreement and SDG goals (see Appendix 1 for the relevant indicators on measurement and monitoring).

4) Will the management of air pollution, and accounting for those costs per tourist, allow decision makers to judge what steps are required to cover costs while transitioning to a greener economy, as part of their commitment to the Paris Agreement and the Sustainable Development Goals (SDGs)?

Tunisia does not have a system in place to monitor ambient particulate matter levels in cities and this posed a difficulty in monitoring tourism emissions in Djerba. In Djerba, the primary source of tourism-related PM emissions detected was from taxis. A more holistic measurement system should include aircraft taxi emissions, an important source of air pollutants in many regions of the world. In Tozeur, PM air emissions caused by tourism are not a primary source of air pollutants, but attention needs to be given to desert dust proliferation as a result of tourist excursions. While air pollutants are very relevant for more urban destinations, it was not possible to detect their relevance in rural destinations in Tunisia.

5) Will the management of land-use, and accounting for those costs per tourist, allow decision makers to judge what steps are required to cover costs while transitioning to a greener economy, as part of their commitment to the Paris Agreement and the Sustainable Development Goals (SDGs)?

In 2015, 9.6% of Djerba's coastline was urbanized, primarily for tourism development. The impacts of climate change are monitored by the Agency for the Protection of Coastal Development (APAL), which has oversight over Djerba's sand coast and dune system. The elimination of dunes due to coastal development for tourist accommodation facilities has left the coastal waterfront unprotected against tidal surges and sea level rise resulting from climate change. Sea level rise threatens to submerge 11% of the total island area, with the main affected area being the commercialized hotel zone. APAL faces financial challenges responding due to the high cost of restoring dunes. Nonetheless, Tunisia is making notable progress on the documented disappearance of key coastal areas that support tourism. In general, the effort to manage and protect coastlines on Djerba needs support. Thus, further measurements and monitoring of the impacts of tourism development and climate change-related vulnerability issues, such as sea level rise, will assist local policy makers in estimating the costs of managing and restoring the coastline and aligning projects to protect the tourism economy. Such data will also contribute to efforts to mitigate and manage coastal areas in alignment

with the Paris Agreement and the SDGs (see Appendix 1 for relevant indicators on measurement and monitoring).

6) What policy pathways will enable Tunisia to gather and use tourism carbon impact data 1) to provide a science-based set of measures for national NDC reporting and 2) to provide a set of local, precise measures of the unaccounted for demands tourism growth places on local resources and utilities, including water, wastewater, energy, solid waste, and land-use?

Per tourist night carbon emissions in Djerba is three times higher than per day, per capita emissions in Tunisia. Electricity is the highest contributor, which is being increased by water desalination on the island. According to the regression models in this report, there is substantial risk of a significant increase in tourism's carbon footprint due to increasing temperatures. This means that tourism will fail to follow the decarbonisation path set by Tunisia of a 41% reduction in carbon intensity by 2030, which is committed to via its NDC report. Therefore, measuring and monitoring tourism's GHG emissions as part of NDC reporting will become increasingly relevant to Tunisia in the next 5-10 years, as climate change impacts increase, and tourism to the country grows. Measuring and managing destinations will be essential for national NDC reporting.

The overall results of this project suggest that Tunisia can benefit from measuring the use of vital resources and monitoring progress towards more sustainable solutions for managing tourism. The overall goals of the project to both measure tourism's resource use and climate change-related impacts, for the purposes of informing local governments, have been met. The final workshops on Djerba Island confirm that policy makers, business people, and academic representatives agree that creating local research and data centers would offer important information enabling a transition to a more efficient tourism economy. The measurement indicators of the ISTI Framework (section 1), as presented in Appendix 1, represent a holistic view of tourism's demands on local resources and climate change-related impacts in Djerba. The monitoring indicators of the ISTI Framework (section 2) were adjusted for the purposes of understanding how data/research centers could assist with the specific challenges on the mainstream tourism island, Djerba and the emerging, desert destination of Tozeur.

References

10YFP Sustainable Tourism Programme, International Symposium, Advancing Sustainable Tourism in a Changing Climate: A side event of the UNFCCC COP22, Main Takeaways. (11 November 2016). http://cf.cdn.unwto.org/sites/all/files/docpdf/10yfpstpcop22ismaintakeaways.pdf Accessed December 28, 2018

10 YFP Sustainable Tourism Program. (2016). *International Symposium "Advancing Sustainable Tourism in a Changing Climate". A side-event within the framework of UNFCCC COP22.* Marrakech, Morocco: UNWTO, UN Environment.

Almuktar, S.A.A.A.N., Abed, S.N. & Scholz, M. (2018). Wetlands for wastewater treatment and subsequent recycling of treated effluent: a review. *Environmental Science and Pollution Research*, 25: 23595. https://doi.org/10.1007/s11356-018-2629-3.

ANGED, GIZ. (2013). *Programme pilote de gestion intégrée des déchets à l'île de Djerba.*

ANPE. (2016). *Etude sur la gestion durable des systèmes insulaires de la Tunisie.* Agence Nationale pour la Protection de l' Environment, Rebublique Tunisienne .

ANPE, GTZ. (2010). *Indicateurs du tourisme durable en Tunisie.*

APAL. (2015). *Lutter contre les vulnérabilités et les risques des changements climatiques dans les zones côtières vulnérables de la Tunisie 2015-2019.*

APAL. (n/a). *Presenation: Programme de Protection du Littoral contre l'Erosion CcôtièreEtudes & TravauxEtudes & Travaux.* Agence pour la Protéction et l' Aménagement du Litoral.

Arbex, M.A., et al. (2012). Air pollution and the respiratory system. *The Jornal Brasileiro de Pneumologia*, 38, 643-655. http://dx.doi.org/10.1590/S1806-37132012000500015.

Bourse, L. (2011). *Profile of Sustainability in some Mediterranean Tourist Destinations: Synthesis: Djerba, Tunisia Based on the case study by Jean Mohamed Mehdi CHAPOUTOT.* Plan Bleu UNEP/ MAP Regional Activity Centre.

Burnett RT, Dales RE, Brook JR, et al. (1997). Association between ambient carbon monoxide levels and hospitalizations for congestive heart failure in the elderly in 10 Canadian cities. . *Epidemiology*, 8:162–7.

CDCGE (Consulting en Développement Communautaire et en Gestion d'Entreprises). (2016). *Projet: Gestion durable des Ecosystèmes Oasiens; Renforcement des capacités pour la gestion durable des écosystèmes oasien. Monographie des oasis traditionnelles du Gouvernorat de Tozeur.* Ministère de l' Environnement et du Développement Durable de la Tunisie.

Colbeck I, Lazaridis M. . (2010). Aerosols and environmental pollution. *Naturwissenschaften* , 97: 117–131.

Cortes-Jimenez, I.; Pulina, M. (2010). "Inbound tourism and long-run economic growth. *Current Issues in Tourism*, 13, 61–74.

Development Policy and Analysis Division . (2017). *World Economic Situation and Prospects: Monthly Briefing.* Department of Economic and Social Affairs, United Nations.

Dłuzewska, A. (2008). Direct and indirect impact of the tourism industry on drylands: the example of Southern Tunisia . *Management of Environmental Quality: An International Journal*, Vol. 19 Issue: 6, pp.661-669, https://doi.org/10.1108/1477783081090489.

Epler Wood, M. (2017). *Sustainable Tourism on a Finite Planet.* London, UK: Routledge.

Epler Wood, M., Milstein, M., & Ahamed-Broadhurst K. (2019). *Destinations at Risk: The Invisible Burden of Tourism.* The Travel Foundation.

Erel Y, Kalderon-Asael B, Dayan U, Sandler A. . (2007). European atmospheric pollution imported by cooler air masses to the Eastern Mediterranean during the summer. *Environ Sci Technol* , 41: 5198–5203.

Eurostat. (2009). *Medstat II: "Tourism and Water", pilot study.* Luxemburg: Eurostat.

Forastiere F, Badaloni C, de Hoogh K, et al. . (2011). Health impact assessment of waste management facilities in three European countries. . *Environmental Health*, 10:53. doi:10.1186/1476-069X-10-53.

García-Ruiz, J. M., & Lana-Renault, N. (2011). Hydrological and erosive consequences of farmland abandonment in Europe, with special reference to the Mediterranean region – A review. *Agriculture, Ecosystems & Environment*, Volume 140, Issues 3–4, Pages 317-338.

Gómez-Calero, M.; Molina, J.A.; Pablo-Romero, M.P. (2014). Research note: Exploring the effect of tourism on economic growth in the Spanish provinces and autonomous communities, 1999–2008 . *Tourism Economics*, 20, 1117–1124.

Gössling, S. and Peeters P. (2015). Assessing Tourism's Global Environmental Impact 1900–2050. *Journal of Sustainable Tourism* , 23(5) 639-659.

Hadjikakou, M. (2014). *Measuring the Impact of Tourism on Water Resources: alternative frameworks (Doctoral thesis).* University of Surrey.

Institut National de la Météorologie (INM). (n/a). *Etude des tendances et des projections climatiques en Tunisie.* Available at: http://www.climadapt-tempus.com/sites/default/files/Belghrissi%20INM-Tunisie.pdf: INM Direction de recherche et développement.

IPCS . (1993). *Benzene.* Geneva, World Health Organization, International Programme on Chemical Safety (Environmental Health Criteria 150.

Karanasiou A, Moreno N, Moreno T, Viana M, de Leeuw F, Querol X. (2012). Health effects from Sahara dust episodes in Europe: literature review and research gaps . *Environ Int* , 47: 107–114.

Kharroubi, A., Tlahigue, F., Agoubi, B. et al. (2012). Hydrochemical and statistical studies of the groundwater salinization in Mediterranean arid zones: case of the Jerba coastal aquifer in southeast Tunisia. *Environmental Earth Science*, 67: 2089. https://doi.org/10.1007/s12665-012-1648-5.

Klepac et al. . (2018). Ambient air pollution and pregnancy outcomes: A comprehensive review and identification of environmental public health challenges. *Environmental Research.* , 167, 144-159. https://doi.org/10.1016/j.envres.2018.07.008.

Kraiem, Z. (2015). *Doctoral thesis: Les nappes phréatiques du Chott Djérid (Sud Est Tunisien): Caractérisation, mécanismes de minéralisation et étude de valorisation.* Sfax, Tunisia: National School of Engineers of Sfax.

Lambert, L. and F.J. Culley. (2017). Innate Immunity to Respiratory Infection in Early Life. *Frontiers in Immunology*, 8, 1570. http://doi.org/10.3389/fimmu.2017.01570.

Landrigan et al. (2017). The Lancet Commission on Pollution and Health. *The Lancet*, 391, 462-465.

Lenzen, M., Sun, Y., Faturay, F., Ting, Y., Geschke, A., & Malik, A. (2018). The Carbon Footprint of Global Tourism. *Nature Climate Change* , 8(6) 522-528.

Mariotti A, Dell'Aquila A. . (2012). Decadal climate variability in the Mediterranean region: Roles of large-scale forcings and regional processes. *Climate Dynamics*, 38, 1129–1145. doi: 10.1007/s00382-011-1056-7.

Mabrouk, F., McDonald, M., Mocan, S., Summa, T. (2008) *The Tunisian Tourism Cluster*, The Microeconomics of Competitiveness, Harvard University

Mekki, N. (2014, September). *Tunisia: Equality in Gender and Constitution,.* Arab Forum for Citizenship in Transition.

Middleton N, Yiallouros P, Kleanthous S, Kolokotroni O, Schwartz J, Dockery DW et al. . (2008). A 10-year time-series analysis of respiratory and cardiovascular morbidity in Nicosia, Cyprus: the effect of short-term changes in air pollution and dust storms. *Environ Health* , 7: 39.

NDC Tunisia. (2015). *Intended Nationally Determined Contribution- Tunisia.* Republic of Tunisia, Ministry of Environment and Sustainable Development.

Querol X, Alastuey A, Puicercus JA, Mantilla E, Miro JV, Lopez-Soler A et al. . (1998). Seasonal evolution of suspended particles around a large coal-fired power station: particles levels and sources. *Atmos Environ* , 32(11): 1963–1978.

Regulatory Indicators for Sustainable Energy (RISE). (2018). *RISE scores.* Retrieved from RISE: http://rise.worldbank.org/scores

Reseau Alternatif des Jeunes - Tunisie. (2018). *Climate Finance in Tunis.* Green Barometer.

Rico Amoros, A.M., Olcina-Cantosa, J., Sauri, D. (2009). *Tourist land use patterns and water demand: Evidence from the Western Mediterranean.* Land Use Policy, 26(2), 493–501.

Rodriguez S, Alastuey A, Alonso-Pe´rez S, Querol X, Cuevas E, Abreu-Alonso J et al. . (2011). Transport of desert dust mixed with North African industrial pollutants in the subtropical Saharan air layer. *Atmos Chem Phys* , 11: 6663–6685.

Safaa M. Raghab, Ahmed M. Abd El Meguid, Hala A. Hegazi. . (2013). Treatment of leachate from municipal solid waste landfill. *HBRC Journal*, 9:2. doi: 10.1016/j.hbrcj.2013.05.007.

Salem, M. B. (2015). Social, Economic and Political Dynamics in Tunisia and the Related Short- to Medium-Term Scenarios. *Instituto Affari Internazionali*, 2-3.

Samoli E, Nastos PT, Paliatsos AG, Katsouyanni K, Priftis KN. . (2011). Acute effects of air pollution on pediatric asthma exacerbation: evidence of association and effect modification. *Environ Res* , 111: 418–424.

Sandstrom T, Forsberg B. (2008). Desert dust: an unrecognized source of dangerous air pollution? . *Epidemiology*, 19: 808–809.

SONEDE. (2015). *Etude d'impact sur l'environnement de la station de dessalement de projet de realisation de la station de dessalement d'eau de mer à Djerba .*

Tortella, B. D., Tirado, D. (2011). *Hotel water consumption at a seasonal mass tourist destination. The case of the island of Mallorca.* Journal of Environmental Management, 92(10), 2568-2579.

Tunisia 2nd Biennial Report to the UNFCCC. (2016). *(In French) Deuxième Rapport Biennal de la Tunisie Convention Cadre des Nations Unies Sur les Changements Climatiques.* Ministère des Affaires Locales et de l'Environnement .

UN Water. (2017). *The United Nations World Water Development Report 2017: Wastewater the untapped resource.* United Nations.

UNEP. (2015). *Global Waste Management Outlook.* United Nations Environment Programme.

UNWTO, UN Environment. (2018). *Baseline Report on the Integration of Sustainable Consumption and Production Patterns into Tourism Policies. Draft for consultation.*

US EPA. (2018). *Particulate Matter (PM) Pollution.* Retrieved Sept 20, 2018 at: https://www.epa.gov/pm-pollution: United States Environmental Protection Agency.

USAID. (2015). *Climate Change Information Factsheet, Tunisia.* Retrieved on October 2018.

World Travel and Tourism Council (WTTC). (2018). *Travel & Tourism: Economic Impact.* London.

WRI, C40 Cities, ICLEI. (2014). *Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC). An Accounting and Reporting Standard for Cities.* Retrieved July 24, 2016 at: http://www.ghgprotocol.org/city-accounting.

Zekri, S., Mbaga, M.,Fouzai, A. & Al-Shaqsi, S. (2011). Recreational Value of an Oasis in Oman. *Environmental Management* , 48:81–88 DOI 10.1007/s00267-011-9678-4.

Appendix 1.
List of policy interlocutors

Name	Title	Organization
TUNIS		
Mohamed Zmerli	Chef de Projet	Ministère des Affaires et de l'environnement
Taoufik Sayadi	Responsable Passation des Marches	Ministère des Affaires et de l'environnement
Aroussia Khamassi	Urbaniste General, Directeur du Patrimoine et l'Environnement	ONTT, direction tourisme
Fethi hanchi	Director of Rational use of Energy	National Agency for Energy Conservation
TOZEUR		
Aïd zaouch	President	Southern Development Council
Wassila Hedfi	Vice Mayor	Tozeur Municipality
Nidhal Hedfi	President	Societe du complexe industriel et technologique de Tozeur
Anis Zayana	Director General	Hotel Ras el Ain - Tozeur
Habib khalifa	Director General	Propriétaire de Dar Tozeur
Abdelmalek sabour	Manager	Pearl of the Desert – travel agency
Abdelbacet Hamrouni	President	National Sanitation Office - Tozeur
DJERBA		
Lassad el Hajjem	Mayor	Midoun Municipality
Tarek Mrabet	Head of the council	Midoun Municipality

Anwar Bou Chamia	Council Member	Midoun Municipality
Njeib Eloueti	Council Member	Midoun Municipality
Esmahen Belhajyahia	Council Member	Midoun Municipality
Saber Ben Hammouda	Council Member	Midoun Municipality
Houcine Jrad	Mayor	Houmt Souk Municipality
Khaled Zerria	Chairman of the committee of decentralization and international cooperation	Houmt Souk Municipality
Meriem Fitouri	Council member (adviser)	Houmt Souk Municipality
Chrazad Laghouan	Mayor	Ajim Municipality
Nejib Bouabidi	Director of ISET - Djerba	ISET - Djerba
Amal Hachani	Commissiare Regionale au Tourisme Djerba - Zarzis	Office National du Tourisme Tunisien
Hamda Abdellaoui	President	Federation of Travel Agencies
Jaleleddine Henchiri	President	Federation of Hotels

Appendix 2.
Workshop Attendees

November 15, 2018

Name	Institution
Abdelwahab Mahdhi	The ISET of Djerba
Adel Bouziri	The ISET of Djerba
Anis Ben Omrane	The ISET of Djerba
Hazar Chtioui	The ISET of Djerba
Issa Abichou	The ISET of Djerba
Kaouther Razouen	Fiesta Beach
Lotfi Belhajmhamed	The ISET of Djerba
Megan Epler Wood	Harvard
Nouha Boussoffra	The ISET of Djerba
Olfa Ben Taazaeit	The ISET of Djerba
Olfa Helali	ISET Djerba
Slim Ben Salem	Fiesta Beach
Sofia Fotiadou	Harvard
Taher Ben rejeb	The ISET of Djerba
Taher Idoudi	The ISET of Djerba
Tanner C. Knorr	EplerWood International
Youssef Ben Slama	Radisson Blu

November 16, 2018

Name	Institution
Abdelbacet HAMROUNI	Office National d'Assainissement- Tozeur
Adel Fitouri	CRDA Medenine
Adnen Ben Hassin	GEEC
Adnene Ben Hassine	GEEC
Aïd ZAOUCH	Office de Développement de Sud (Tozeur)
Aroussia Khamassi	ONTT, direction tourisme
Bechir Chaouachi	ENIG
Chrazad Laghouan	Ajim Municipality
Esmahen Belhajyahia	Midoun Municipality
Faiza Sekrafi	Journalist-TV
Farhat Ben Tanfous	Les Jardins de Toumana
Hassen Hichri	Midoun Municipality
Hedi Chaffar	STEG Medenine
Hichem Hassine	Houmt Souk Municipality
Hichem Mahouachi	Commissariat régional du tourisme - Djerba-Zarzis
Houcine Jrad	Houmt Souk Municipality
Jaleleddine Henchiri	Federation of Hotels
Kamel Boubi	Commissariat régional de dévéloppement Touristique
Khaled Zerria	Houmt Souk Municipality
Khalil Mrabet	Midoun Municipality
Khmaies Boubtane	Journalist-TV
Lotfi Msadki	APAL Gabes
Mabrouk Chabani	Private society of waste collection
Megan Epler Wood	Harvard

Mehdi Helali	Fiesta Beach Djerba
Meriem Fitouri	Houmt Souk Municipality
Messaoud Ben Hadid	Djerba Ajim
Mohamed Mehdaoui	Radio
Mohamed Ridha Fourati	SONEDE Medenine
Mohamed Zmerli	Ministère des Affaires et de l'environnement
Monsef MAKHLOUF	Fédération Régionale de l'Hotelerie du Sud ouest
Nabil Gasmi	Chambre de Développement du Tourisme Oasien et Saharien
Naceur Bouabid	ASSIDJE (Assosciation-green Djerba)
Nader Khmili	Delegate Houmt Souk
Olfa Helali	ISET Djerba
Rafik Bechoual	ISET - Djerba
Raoudha Ben Ltaeif	ANETI Djerba
Raoudha Boutar	Radio
Sami Ben Issa	Houmt Souk Municipality
Sami Saadi	Yadis Djerba
Sfaya Mourad	CIT de Tozeur (Pole de Djérid)
Slah Bouchhiwa	SONEDE Djerba
Sofia Fotiadou	Harvard
Somaya Zbidi	Tozeur Municipality
Tanner C. Knorr	EplerWood International
Tarek Mrabet	Midoun Municipality
Walid Triki	DRD Medenine
Wassila HEDFI	Tozeur Municipality
Yosr Hamouda	FRH South-East