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Research article

Risk management and policy implications for concentrating solar power technology investments in Tunisia

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ABSTRACT

Concentrating solar power (CSP) is a promising technology in Tunisia. However, its diffusion is facing many barriers which deter investments. Through the analysis of a CSP plant in Southern Tunisia by using the Global Risk Analysis (GRA) method, we try to analyze the main risks faced by investors. The main objective of this research is to identify and analyze the risks faced by CSP investors in Tunisia and develop strategies that should be adopted to accelerate the process of diffusion of this technology.

This analysis allows us to conclude that the CSP project is very exposed to political, financial, physical-chemical, legal, and strategic hazards. Moreover, we show that among the four phases of the project, the preparation phase is the most vulnerable to hazards.

In fact, the GRA method makes it possible to determine the list of the major risks, such as the risk of not obtaining permission to build a CSP plant, the risk of non compliance with the deadline, the risk of failure to achieve the expected performance, the risk of insufficient access to capital, and the risk of conflicts with local residents.

In order to de-risk CSP technology in Tunisia, we propose some strategies, such as strengthening the public-private partnerships, using participatory approaches, creating local employment, etc.

1. Introduction

While the benefits and advantages of energy for economic development are multiple and well known, it is rather the damages related to our energy-intensive societies that deserve the greatest attention. According to a recent report prepared by the Renewable Energy Policy Network for the 21st Century (REN21, 2018), the total final energy consumption was dominated by fossil fuels (oil, natural gas, and coal) by about 79.5%, in 2016. Therefore, energy demand is mainly covered by the use of fossil fuels which are the main sources of greenhouse gas (GHG) emissions.

In fact, the increase of GHG concentrations in the atmosphere is the main cause of climate change. As a result, the prevention of the catastrophic consequences of the climate change requires the stabilization of the atmospheric concentration of these GHG and especially the carbon dioxide (IPCC, 2007). In this case, the challenge for all countries is to implement a transition to a safer and less carbon emitting energy system without hampering economic and social development (IEA, 2007). The transition to renewable energies (RE) is the evident solution to satisfy the increasing demand while respecting the environment and ensuring a green economic growth (Omri et al., 2015a).

Moreover, many recent reports have indicated that transition towards RE has already started as a result of the increase of the installed capacity and cost competitiveness of wind power and solar PV (IRENA, 2018; REN21, 2018). In fact, the year 2017 presented a new record-breaking for the RE sector since it is marked by an impressive decrease of the costs, the expansion of investments, and the development of the installed capacities (REN21, 2018).

Solar energy is one of the most promising RE due to its competitive costs and its abundance in many countries (Astolfi et al., 2017; Sindhu et al., 2016). The two main solar technologies are the concentrating solar power technology (CSP) and the solar photovoltaic technology (PV) (Mekhilef et al., 2011).

The comparison of the corresponding costs of the different RE options is often based on the use of levelized cost of electricity (LCOE). This comparison leads to the fact that PV is more competitive than CSP (IEA, 2014; Pietzcker et al., 2014).

Joskow (2011) criticized the use of LCOE because it undervalues dispatchable power plants compared to the intermittent electricity generating technologies. In fact, while PV is an intermittent generating

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technology, CSP plants can generate dispatchable power when they are equipped with thermal storage systems. In this case, it is possible to store heat energy obtained during the day in order to be transformed into electricity at night, which facilitates its integration into the existent electricity grid (Brand et al., 2012; Trieb et al., 2014).

In fact, CSP technology with a thermal storage represents one of the few renewable technologies that can offer dispatchable electricity (IEA, 2010; Lilliestam et al., 2018). The assessment of the benefits and of the economic advantages of the CSP dipatchability was detailed in many studies, such as that of Poullikkas et al. (2010).

Although dispatchability is a very important asset for CSP technology, the grid stability aspect regarding the increasing penetration of RE should be treated seriously. In fact, the increase of the proportion of RE in the electricity mix can face many operational challenges, such as the voltage stability of the grid and the load balancing. Hence, it is necessary to ensure the flexibility of the grid and the development of the necessary transmission infrastructure.

Unlike CSP, solar PV is an intermittent technology which, in order to become dispatchable, needs a separate storage system like batteries. Nowadays CSP with a thermal storage is less expensive and more competitive than PV with batteries. However, the maintaining of this advantage in the future is not certain and depends a lot on the future evolution of the costs of PV cells and batteries (Lilliestam et al., 2018).

Therefore, it is clear that CSP technology with a thermal storage has many advantages compared to the solar PV and wind power. However, the reality shows that solar PV and wind power are winning the battle and there is a risk that CSP technology will remain in its small niche if the support from policymakers remains insufficient (Lilliestam et al., 2018). In fact, in 2017, the cumulative PV capacity reached 402 Giga watt (GW) compared to just 4.9 GW for CSP (REN21, 2018).

Hence, despite the advantages of CSP technology, the achievements are modest. This fact proves that the widespread diffusion of CSP technology is facing several obstacles (del Rio et al., 2018; Haas et al., 2018) and requires an adequate support policy to take off (Lilliestam et al., 2018).

In fact, the Middle East and North Africa (MENA) region is one of the most favorable regions for large-scale solar energy deployment. Moreover, the high direct normal irradiation (DNI) in North Africa can make this region a major exporter of the electricity produced by CSP plants in the desert and then transmitted to Europe (IEA, 2010). For these reasons, the feasibility and financing aspects of the export of electricity produced by CSP technology in North Africa have attracted the attention of several researchers, such as Kost et al. (2011), Trieb et al. (2012, 2011), Viebahn et al. (2011), Williges et al. (2010), etc. Moreover, the advantage of the thermal storage can make the electricity produced by CSP plants an important component of the future electricity mix. Therefore, the African deserts will be a source of baseload and dispatchable power (Pfenninger et al., 2014; Trieb et al., 2014).

For these reasons, there are many studies that focus on CSP technology in the MENA region, especially the barriers and risks hindering its large scale development (Komendantova et al., 2012; Lilliestam et al., 2012). Morocco has attracted the attention of many researchers. However, to our best knowledge, there has not been yet any study that deals with barriers and risks of investing in CSP technology in Tunisia.

In fact, Tunisia enjoys a great potential of solar resources and many suitable factors for large scale deployment of CSP technology (Balghouthi et al., 2016). However, there are no achievements that are in harmony with the enormous solar potential of this country. In 2017, the cumulative installed capacity of solar PV accounted for about 47.1 Megawatt electric (MWe) and there has not been yet any large-scale operational CSP plant in Tunisia (IRENA Resource, 2018). Nevertheless, there are many planned plants, such as a parabolic trough plant of 50 MW and another one of 2500 MW using a power tower technology. Although these projects were planned many years ago, the construction has not begun yet.

Furthermore, despite the advantages that can be offered by the use of CSP technology in Tunisia, achievements in this field are inexistent. This fact leads us to set the following questions: what are the most challenging barriers that hinder CSP investments in Tunisia? In other words, what are the risks of investing in CSP technology in Tunisia? And what are the effective policy measures to mitigate these risks?

To answer these questions, we used a risk management approach and particularly a Global Risk Analysis (GRA) method in order to assess the risks concerning the case of a CSP plant that will take place in the South of Tunisia.

As a consequence, our study is structured as follows. The theoretical background is presented in section 2. Section 3 is devoted to the current status of CSP technology. The Barriers facing the CSP expansion are detailed in section 4. Then, section 5 describes the case study of the CSP plant, introduces the GRA method that will be applied, and explains all the steps required for the application of this method. The results are described in section 6 along with a related discussion and suggestions in terms of policy implications. Finally, the concluding remarks are provided in section 7.

2. Theoretical background

Climate change is a serious threat to the well-being of future generations and economic growth. To deal with this threat, it is necessary to reduce GHG emissions by using adaptation and mitigation measures in order to move to a low carbon economy (IPCC, 2007). However, the current energy system appears to be highly dependent on fossil fuels and the process of transition to RE is relatively slow mainly in the heating, cooling, and transport sectors (REN21, 2018).

This section will focus on the transition to RE, the barriers facing this process, particularly the “carbon lock-in” effect, and finally the importance of RE policy in eliminating these barriers.

2.1. The transition to RE

RE satisfy the same needs as conventional energies. Indeed, they can be used to generate electricity; in this case they can supply electricity to farms, homes and buildings. RE can also be used for heating, cooling, and transport (REN21, 2018). Besides, RE can offer rural areas the opportunity of access to clean and decentralized energy sources (OECD, 2012).

In recent years, the transition to RE has been motivated by two main reasons. The first one is linked to the growing concern with sustainable development (Elum and Momodu, 2017; González et al., 2017; Omri et al., 2015b). The second reason concerns the great attention given to the concepts of “green recovery” and “green growth” since the economic crisis of 2008 (Omri et al., 2015a).

The reduction of GHG (Goh and Ang, 2018) and the creation of green jobs (Fragkos and Paroussos, 2018) are among the most known advantages of the transition to RE. Although the benefits of RE use are well known and efforts for large-scale exploitation are provided in many countries, fossil fuels still dominate (REN21, 2018). In fact, theoretical arguments and empirical research studies indicated that the current energy system is locked-in a complex context of high-carbon technologies and infrastructures (Arentsen et al., 2002; Davis et al., 2010; IEA, 2011; Rip and Kemp, 1998; Schmidt and Marschinski, 2009).

Moreover, despite the awareness of the damage caused by the use of fossil fuels, the industrialized economies are in a locked-in position in favor of fossil fuels (Unruh, 2000) and attempts to turn to RE are facing many barriers (Painuly, 2001). In fact, the main barrier to the rapid diffusion of RE is the carbon lock-in effect which creates a market and policies that can slow down or even block the spread of RE technologies, even though they have many environmental and economic benefits (Unruh, 2002, 2000). This concept will be explained in the following sub-section.

2.2. The carbon lock-in effect

The technological lock-in effect has been increasingly explained by many researchers since the mid-1980s (Arthur, 1989; Cowan, 1990;

David, 1985; Liebowitz and Margolis, 1995; Perkins, 2003). The explanations given for the existence of the technological lock-in effect are: the existence of technological paradigms and the increasing returns to adoption.

The first explanation of the technological lock-in effect is the fact that the features and the orientation of technological progress are strongly influenced by the cognitive framework of the actors in the technological community. Nelson and Winter (1977) used the term "*technological regime*" to characterize these frameworks, while Dosi (1982) used the term "*technological paradigm*". Although the terms used are different, their senses are quite similar.

According to Perkins (2003), the consequence of the existence of these mental frameworks called technological paradigms or technological regimes is that the efforts made to bring forward the efficiency of technology often focus on specific and well-defined directions which are based on past accomplishments, common beliefs and state of knowing of the technological community. This situation can create powerful exclusionary effects on innovative technological possibilities and solutions outside the "dominant technological paradigm". This "exclusion effect" was explained by Dosi (1982).

The second explanation given to the technological lock-in effect, which is strongly linked to the first one, is the presence of increasing returns to adoption which represent a positive feedback process and make an adopted technology more attractive than a new one. This idea was well explained by Arthur (1989) and David (1985) who believe that in a situation where many technologies are competing, the existence of increasing returns implies that the technology that has benefited from initial adoption advancement may eventually be more performing. There are generally four classes of increasing adoption returns that are involved in the technological lock-in effect. These four classes are: economies of scale, learning economies, adaptive expectations, and network economies (Arthur, 1994).

Recently, the technological lock-in concept has interested many researchers who are involved in the fields of technological change and the environment. These researchers highlighted the negative effects of the use of fossil fuels on climate change and the barriers facing industrialized economies in moving to a low-carbon energy system. This problem is caused by the carbon lock-in effect (Kemp, 1994; Mattauch et al., 2015; Rip and Kemp, 1998; Unruh, 2000).

Indeed, since the 1990s, a growing interest has been given to the effect of carbon lock-in, which is considered as an obstacle to the transition to low-carbon technologies (Ayres, 1991; Freeman and Soete, 1997; Kemp, 1994; Unruh, 2000). Mattauch et al. (2015) confirmed that the major obstacle to the transition to a low-carbon economy is the carbon lock-in effect. They considered that fossil fuels dominate the market although their alternatives, mainly RE, are dynamically more efficient.

On the other hand, Pinkse and Buuse (2012) considered that past investments in fossil fuels can influence the perception of decision-makers in oil companies about the risk-return couple, bringing them to see more opportunities in their previous trajectory than in the less familiar RE trajectory.

It should be emphasized that the carbon lock-in situation is not a permanent situation but rather a persistent state that creates barriers to fossil fuel alternatives (Unruh, 2000). Indeed, this effect is manifested in reality by a situation in which investments in RE projects face several barriers of different types (economic, institutional, financial, social, etc.) which represent significant risks for investors. In the next subsection, we will focus on the necessity of RE policy to eliminate these barriers and to accelerate RE development.

2.3. The role of RE policy

Policy makers either in the developed or developing countries are promoting RE technologies by implementing specific policies which include fiscal incentives, targets, public support, and new regulations. By the end of 2017, 179 countries had set RE goals (REN21, 2018).

The main barrier to RE diffusion is its high cost compared to conventional sources (Mezher et al., 2012). Therefore, the expansion of the RE sector requires government support either through fiscal incentives, targets, public financial support, and regulations to encourage investment in this sector (REN21, 2018), or through other instruments, such as the elimination of perverse subsidies and the internalization of negative environmental externalities caused by fossil fuels (Unruh, 2000).

Although the costs have significantly declined in recent years, RE technologies still require support schemes to keep this trend. In fact, in 2017, the global weighted average LCOE of onshore wind plants reached USD 0.06/kilowatt-hours (kWh), while for utility-scale of solar PV was around USD 0.10/kWh. However, CSP technology has been dragging out for many years, by having a global weighted average LCOE around USD 0.22/kWh (IRENA, 2018).

Despite the abundance of RE resources, their share remains modest due probably to the small-scale production, the insufficient learning effects, and the lack of institutional support. The government policy based on goals, strategies and instruments is very important for the development of RE. In fact, Research and Development (R&D) subsidies and the creation of market niches are recommended to stimulate these new options (Kemp, 1994).

Researchers and analysts who studied and evaluated RE support systems used many different ways to describe and classify them. The most used typology is the one that differentiates between price-based and quantity-based instruments (Menanteau et al., 2003). In fact, the instruments and mechanisms used to accelerate the diffusion of RE are various, they include: Renewable Porfolio Standard (Xin-gang et al., 2018), Green Certificates (Hustveit et al., 2017), Feed-in Tariffs (Böhringer et al., 2017), and Renewable Obligation (Nock and Baker, 2017).

3. Current status of CSP technology

CSP plants produce electricity by using heat. In a similar manner as a magnifying glass, mirrors concentrate the direct solar radiation on a receiver filled with a heat transfer fluid. The heat absorbed by the fluid is used to produce steam that drives a turbine to produce electricity.

Unlike solar PV technology, CSP technology has the advantage of storing heat energy for later conversion into electricity. In this case, the production of electricity in the absence of sunlight is possible by using thermal energy storage systems. This characteristic enables CSP plants to provide dispatchable power.

The CSP plants can be divided into four different technology types: parabolic troughs, linear Fresnel mirrors, central receiver systems, and dish Stirling systems. The CSP market is still dominated by parabolic troughs.

Areas favorable to the development of the CSP technology are regions that enjoy a maximum DNI, such as the MENA region, Central Asia, South Africa, South of Spain, etc. The solar limit required for potential sites is set at a DNI of at least 2000 kWh/m^2/year due to economic constraints.

Unlike most natural resources, solar energy in the form of DNI exists in all continents. In addition, the populated areas are quite close and can be connected to those regions that have excellent solar conditions. Indeed, the electricity produced in the sunniest areas of the planet can be transmitted by means of high voltage direct current (HVDC) lines over several thousand of kilometers.

With the exception of Spain and the United States of America (USA), which are leaders in CSP technology, very few countries have large CSP facilities connected to the national electricity grid with a capacity of more than 50 MW. These countries are China, India, Morocco, South Africa, and the United Arab Emirates (UAE).

The new CSP installed capacity in 2017 was 100 MW and the global installed capacity reached 4.9 GW by the end of 2017 (REN21, 2018). On the other hand, Spain and the USA continue to be the leaders in

terms of existing CSP capacity, but the growth of the CSP market is driven outside of these traditional markets and directed to new emerging markets, such as South Africa, India, China, and Morocco.

With the exception of Morocco and the UAE, which are key drivers of CSP expansion, the development of CSP technology in the MENA region is still below expectations regarding the enormous potentials in these countries. However, in Saudi Arabia and Kuwait, many CSP facilities are under construction which can shift the CSP activity from Spain and the USA to the MENA region in the next few years. In fact, the MENA region is one of the most favorable regions for the large-scale deployment of CSP technology. Moreover, this region is characterized by exceptional geographical features, such as high DNI, low precipitation, especially in desert areas, and the existence of flat and unused lands that are not far from power grids and roads. So, this region is very convenient for the widespread deployment of CSP technology and the export of the electricity produced to Europe using HVDC lines.

The economic impacts resulting from the development of a local industry of CSP technology in North Africa was explained in many papers. For example, Kost et al. (2012) demonstrated that the development of a CSP market in North Africa will positively influence the local economies and significantly contribute to the national gross domestic product. They actually found that total generated revenues from the potential market size of CSP plants could attain 120 Billion Euros by 2030.

4. Barriers to CSP expansion

The cost of CSP technology is one of the most prominent barriers to its large scale diffusion (del Rio et al., 2018). Therefore, support policies must be implemented in order to make investment profitable for existing firms, encourage new entrants to the CSP market, support innovation, and make CSP technology more competitive.

Lilliestam et al. (2018) considered that the CSP industry is facing two crucial risks. The first one is that many experienced firms leave the CSP market, which leads to the loss of a lot of tacit knowledge, know-how, and experience. The second risk is that developers and operators ignore innovations by using well-known components in order to avoid technology risks. This attitude is a great barrier to cost reduction.

On the other hand, the financing risk is among the risks that have attracted much attention. For example, Lilliestam et al. (2012) considered that, among the major barriers to scaling-up CSP technology, there are the expansion of electricity transmission lines and financing risks. In fact, the lack of experience with CSP investment in most emerging economies increases financing risks. Indeed, these countries are suffering from small financial markets, which are not convenient for financing large scale CSP plants, especially in terms of high interest rates and the absence of debts with long maturities (Stadelmann et al., 2014). In this case, reducing these risks is necessary to encourage developers and scale-up private investments.

Technical risks are also of a great importance. Indeed, Amato et al. (2011) carried out a very original study by assessing the risks associated with business interruption and loss of assets resulting from the emergence of undesirable internal or external events. These authors identified a list of critical hazards, such as malfunction of the orientation system, turbine failure, turbine leakage, salt solidification, and orientation system stopping.

In fact, there are many other country-specific analyses that focused on the barriers that hamper the development of CSP technology in some countries, such as Chile (Haas et al., 2018) and China (Zongxian et al., 2012), or some other regions, like the European Union (del Rio et al., 2018) and the Sub-Saharan Africa (Labordena et al., 2017).

On the other hand, the MENA region has attracted the attention of many researchers. For example, Komendantova et al. (2012) conducted three stages of interviews with experts to investigate their perceptions of risks in the case of CSP projects in North Africa. The results of unstructured expert interviews showed that bureaucratic procedures and corruption have been identified as significant barriers by more than half of all the interviewed experts. Other risks, such as the instability of national regulations, the low level of political stability, and the absence of guarantees from national governments, have also been identified as significant barriers.

Although political corruption and bureaucracy are considered as the main concerns of investors in North Africa (Komendantova et al., 2011), the availability of water in the MENA region is also a serious challenge that should be taken into account (Balghouthi et al., 2016; Belgasim et al., 2018; Xu et al., 2016). In fact, CSP plants require a large amount of water for the cooling process and for cleaning mirrors. However, in arid locations where the annual irradiance levels are high, there is a scarcity of water. This problem can possibly be solved by the use of dry cooling technology. For example, Trabelsi et al. (2016) showed that a CSP plant with dry cooling can reduce water consumption by 93.3%.

Morocco is the country of the MENA region that has attracted much attention over the past few years. For example, Wiesinger et al. (2018) evaluated a very important technical risk which is the erosion effect on the glass due to airborne sand and dust in two sites in Morocco. This risk can increase the losses of optical energy and also the operation and maintenance costs.

On the other hand, Medina et al. (2015) showed that, for the case of companies without an earlier presence in Morocco, uncertainty, insecurity and informality are the main obstacles affecting the decision to invest in the CSP sector. Regarding companies that are already active in Morocco, financial and legal barriers are of a great importance. For the same case of Morocco, Mahia et al. (2014) conducted a survey in order to examine the potential of CSP market and barriers for establishing a CSP manufacturing industry. They also showed that policy related barriers, such as the absence of fiscal and legislative framework for CSP development, are more crucial than entrepreneurial or market barriers. However, other studies discussed rather risk reduction strategies. For example, Frisari and Stadelmann (2015) examined the importance of national policy makers and international finance institutions in de-risking CSP technology in India and Morocco. Some other studies focused on de-risking CSP investments in the MENA region. For example, Schinko and Komendantova (2016) employed an LCOE model in order to analyze the impacts of a de-risking approach on the cost of electricity from CSP in four specific North African countries (Algeria, Egypt, Morocco, and Tunisia). They showed that in order to have a weighted average cost of capital (WACC) in North Africa equivalent to that in Europe, the CSP costs should be reduced by 39%. Trieb et al. (2011) proposed long term power purchase agreements as a de-risking tool for CSP investments in the MENA region.

Although the studies that addressed risks for the case of CSP technology are multiple and treated many countries, Tunisia has not received yet the attention of researchers and there is no study that deals with CSP barriers in Tunisia.

In addition to that, the existing scientific literature has used expert interviews, literature reviews, surveys, and scenario analyses, but the GRA method has not been used yet for the case of a CSP project. In fact, using this method in an environmental study is new and innovative since there is only one published study that applies the GRA method for the case of a wind farm, which is that of Desroches et al. (2016). Actually, this method is usually used for studies in the field of chemistry, industry, and mainly medicine, such as the one by Mazeron et al. (2014).

Therefore, the aim of this paper is to fill in this gap by making two contributions to the existing literature: i) treating the barriers to CSP deployment in Tunisia; ii) using the risk management approach and particularly the GRA method for the case of a CSP project.

5. Method and data

In this section, we will briefly introduce the case studied which concerns a CSP plant, then we will describe all the steps of the GRA

method, and we will finish by applying this method to analyze all the risks that hinder the implementation of this CSP project.

5.1. Case study: a CSP project in Tunisia

We chose to study the case of the first CSP export project between the Sahara region and the South of Europe. This CSP power plant will be established in Southern Tunisia, which is characterized by a favorable solar radiation level of 2500 kWh/m^2/year.

The installed capacity will be 2250 MW: a first stage of 250 MW and a second stage of 2000 MW. This mega CSP project consists of the construction of a CSP power plant using the solar tower technology with thermal storage, the transmission of the produced electricity to Italy using underground and sea cables, and finally the electricity sale in the European energy market (see Table 1).

The British developer of this CSP project estimated that the overall cost will be around 10 billion Euros. Once operating, this project will have many positive impacts on the Tunisian economy in terms of job creation and implementation of an industrial area devoted to solar technologies in Southern Tunisia since most of the components will be locally manufactured.

In fact, the feasibility study of this project began in 2009, however, until now, the construction has not started yet. The project is a perfect illustration of the existence of many barriers to the investment in CSP technology in Tunisia. In order to analyze all the barriers and risks faced by the developers, we used a risk management approach and especially the GRA method that will be explained in the next sub-section.

Table 1
The main features of the CSP project.

Location	South of Tunisia
Annual generation	9000 Gigawattheure (GWh)
Area	10,000 ha
Technology	CSP tower technology with thermal storage
Storage equipment	Molten salt
Status	Partially permitted

5.2. The GRA method

The GRA is a global analysis method which is used to appreciate and manage risks of different natures, such as company's risks, project risks, and product risks, following an invariable process. Its specificity depends on the nature of the considered system and the mapping of the considered hazards and not on the actual analysis process.

The GRA is the name given by Desroches (2013) to the up-to-date Preliminary Risk Analysis (PRA) method which was developed in the 1960's in the aerospace industry and recently extended to many other sectors, including military, chemistry, transport, medicine, and more recently the environment. This analysis is particularly used in health organizations and civil aviation. This paper presents the first application of the GRA for the case of a CSP plant.

In fact, the GRA is *a priori* (proactive), an analytical, bottom up, and semi quantitative risk analysis method (Desroches et al., 2016) which implements all the risk analysis and management steps in compliance with the ISO 31,000:2018 norm (an international standard that provides principles and guidelines for risk management). Besides, it includes context establishment, risk identification, risk assessment, initial risk reduction (prevention/protection), and residual risk assessment and management (monitoring/insurance taking). It can be used for the management of risks of different natures, such as enterprise risk, project risk, and product risk (Desroches, 2013).

Moreover, the GRA is based on the accident scenario presented in Fig. 1. An accident scenario is defined as a sequence or a combination of events ending up in an accident (A) that has consequences (S). This scenario begins with the occurrence of a contact event or an exposition factor (EF) which creates the exposition of system (S) to a hazard (H) and therefore, creates a hazardous situation (HS). Then, the exposition of the hazardous situation (HS) to an initiating or a triggering factor (TF) leads to the accident (A). Finally, the occurrence of a circumstantial event or an aggravating factor (AF) defines and characterises the occurrence, the nature, and the severity of the consequences (S). The causes (hazard, contact event, and trigger event) are related to the parameter “likelihood” of the risk. The nature and the intensity of the consequences are related to the parameter “Severity” of the risk.

The GRA process (Fig. 2) contains three consecutive steps: the system GRA, the scenario GRA and the risk management. The first step consists in: (i) defining the perimeter of the studied system which is the CSP project divided into phases and sub-phases (Appendix A); (ii) identifying all the hazards that could potentially affect the implementation of the project in a hierarchical list composed of generic hazards (generic categories), specific hazards (sub-categories specifically to the system) and hazardous elements/events (translation of the specific hazards in terms of events or elements); and, finally, (iii) identifying the interactions between hazardous events and sub-phases

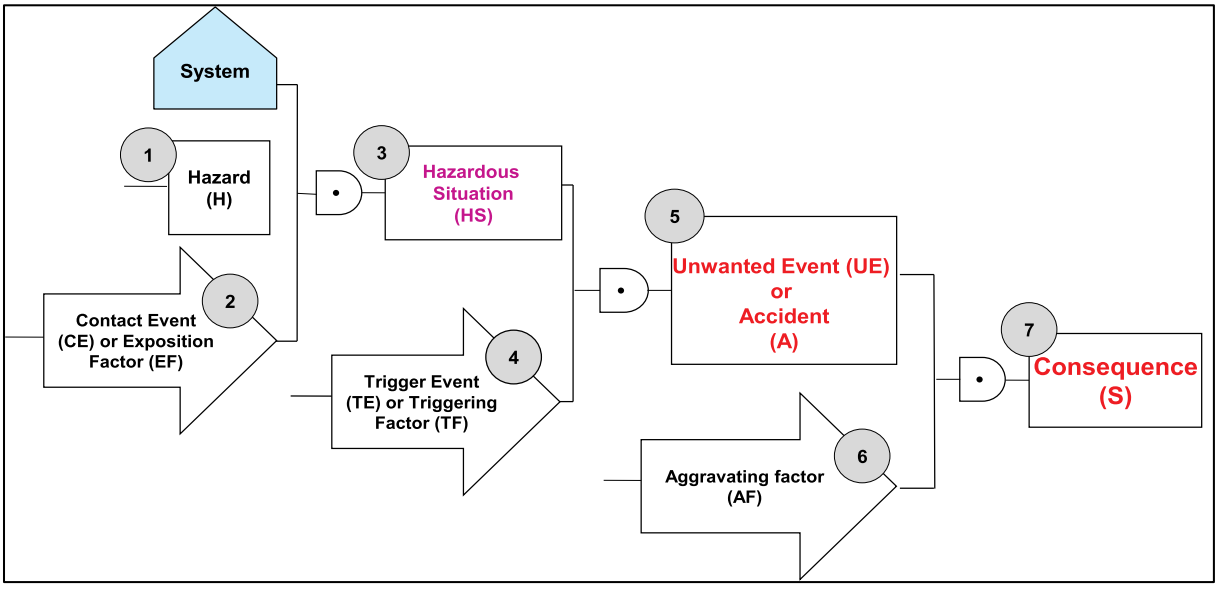


Fig. 1. Accident scenario (Desroches, 2013).

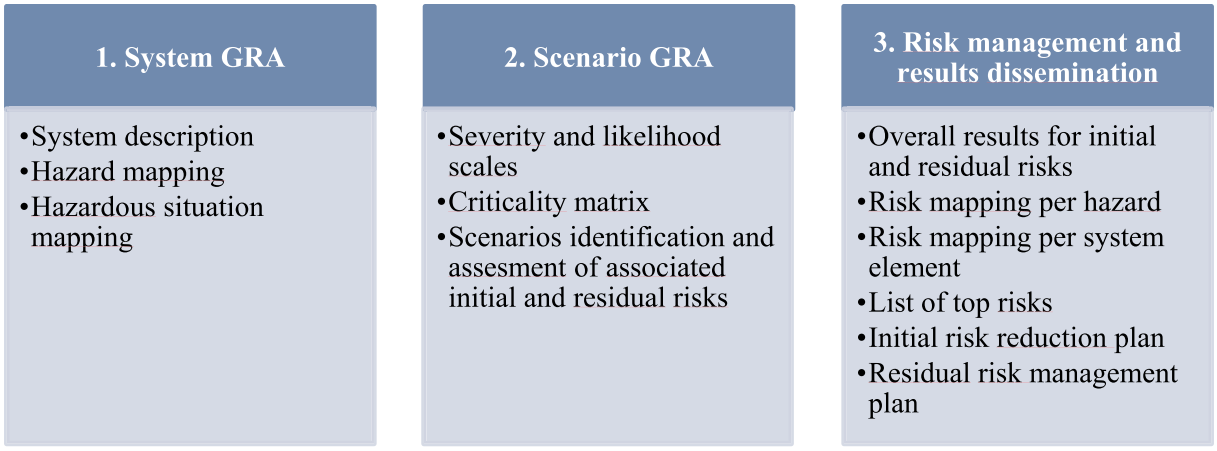


Fig. 2. The GRA process.

of the system leading to hazardous situations. The structure of the mapping of hazardous situations is made by the crossed juxtaposition of the system and the mapping of hazards. The hazard/system interaction is the factor that generates hazardous situations. The interactions should normally be considered as determinists.

The second step, which is the scenario GRA, consists, first of all, in defining the risk assessment parameters, such as the severity and likelihood scales. The severity scale is based on 5 levels of decreasing severity. In compliance with basic principles of dependability, levels S5 and S4 are related to safety whereas levels S3 and S2 are related to the performance of the system (reliability/availability). Concerning the likelihood scale, it is semi-quantitative and based on 5 levels of likelihood, which can be associated with a scale of system-dependent return periods.

Once the assessment scales are identified, the criticality matrix can be built. Finally, the scenarios are identified and described, and the associated initial risks are assessed. If needed (initial criticality C2 or C3), initial risk reduction actions are identified in terms of prevention (decrease of the likelihood) and protection (decrease of severity) and the subsequent residual risk is assessed. Again, if needed (residual criticality C2), residual risk management actions are defined in terms of risk control/monitoring and insurance taking (Appendix D. Scenario_GRA).

The third step, which is risk management and result dissemination, comes after data performing. Therefore, risk mappings are built (Kiviat and Farmer diagrams, but only Kiviat diagrams are presented in this paper) based on the statistical treatment of the analysis. The minimal, average and maximal risks are represented per hazards and per phases. Then, the list of 5–10 major risks is elaborated. Moreover, the practical management of risks is made by the drafting of action sheets and the development of an action follow-up table for initial and residual risks. The software used to perform this analysis is the version 2.091 of StatCart GRA developed by MAD-environment.

The GRA method requires in-depth knowledge of the studied system, which is the CSP project. For this reason, this method has been applied during a six-month internship at the National Agency for Energy Conservation (ANME: Agence Nationale pour la Maîtrise de l'Energie), which is the leader in the institutional organization of energy efficiency and RE in Tunisia. This internship has facilitated meetings with several experts, especially during the numerous congresses organized by the ANME during the training period. In addition, this internship has been an opportunity to benefit from the knowledge and advice of experts and engineers who are working at the ANME. We have also conducted open interviews with the chief executive officer of the project. In addition, we have used a review of the data provided by the ANME, the state electricity utility STEG (STEG: (Société Tunisienne de l'Electricité et du Gaz), and a compilation of secondary sources (books, scientific articles, reports prepared by international organizations, press articles, etc.), as well as a feedback from similar projects, such as the case of the CSP plant in Morocco.

Based on professional advice from experts, managers and engineers in the field of RE as well as experience feedback, we have been able to carry out all stages of the GRA which require a multidisciplinary team. The use of the GRA method for this case is adequate for two main reasons. The first one is that this method is *a priori* (proactive) risk analysis method so, it can be used to analyze risks of a project or an activity before it takes place. This is adequate to this case study since the construction of the CSP plant has not begun yet. The second reason is that the construction of this CSP plant was postponed many times and since 2009, there has been no real progress, which proves that the implementation of the project faces several barriers and risks that hinder its implementation. Hence, a risk analysis using the GRA method is needed to identify the main barriers.

5.3. The application of the GRA method for the case of a CSP project

In this sub-section, we will apply the two first steps of the GRA process, which are the system GRA and the scenario GRA, to the case of the CSP project while the risk management step which comes after data processing will be explained in the result section.

5.3.1. System GRA

The system GRA contains the following steps: the description of the CSP project (Appendix A), the elaboration of the hazard mapping (Appendix B), and finally the elaboration of the hazardous situation mapping (Appendix C. Mapping_HS).

5.3.1.1. Description of the CSP project. The first required step is a detailed description of the CSP project. In fact, a deep analysis of the CSP project enabled us to divide it into four main steps (feasibility study, preparation, construction, and operation), 20 phases, and 51 sub-phases (Appendix A).

5.3.1.2. Elaboration of the hazard mapping. The list of generic and specific hazards has been established similarly to the one proposed by Desroches (2013), and the hazardous events have been determined according to the characteristics of the CSP project in terms of technology, operating methods, required resources, etc. Finally, we got 14 generic hazards (political, environment, insecurity, image, management, strategic, technological, communication and crises, legal, financial, infrastructure and premises, materials and equipment, information system, and physical-chemical) detailed in many hazardous events which can affect the sub-phases of the CSP project (Appendix B). In fact, the hazardous events were identified by reviewing many

studies, such as those of Gabriel (2016), Otieno and Loosen (2016), Painuly (2001), international reports, press articles, feedback from similar CSP systems (for example, the CSP plant Noor in Morocco), and especially discussions with experts working in the ANME and with the chief executive officer of the project.

5.3.1.3. The hazardous situation mapping. The sub-phases of the CSP project have been confronted to the hazardous events in a double entry table in order to obtain the hazardous situation mapping (Appendix C. Mapping_HS). The development of the hazardous situation mapping is the fundamental cornerstone of the analysis since it requires a rigorous and detailed work, and especially a thorough knowledge of the studied project. In addition to that, the determination of hazardous situations is the key step that will be used to determine risk scenarios, risk maps and the list of the major risks.

In fact, each interaction between a hazardous event and a vulnerable element of the system represents a hazardous situation which has been evaluated, when relevant, by assigning a priority index (see Fig. 3). Then, the hazardous situations have been classified into three priority levels according to the priority indexes explained in Table 2. For example, when the interaction between the vulnerable element of the system and the hazardous event is strong and the evaluation and treatment of this hazardous situation is needed immediately, we put a priority index "1" in the cell.

In our study, we have been able to identify 169 hazardous situations, which have been divided into 33 hazardous situations with a priority index "1" (19%), 62 hazardous situations with a priority index "2" (37%), and 74 hazardous situations with a priority index "10" (44%). Then, we have only analyzed hazardous situations with a priority index "1".

5.3.2. Scenario GRA

The scenario GRA contains the following steps: the elaboration of severity and likelihood scales and criticality matrix, and the identification of all possible scenarios according to the process explained in Fig. 1 in order to obtain the scenario GRA (Appendix D. Scenario_GRA).

5.3.2.1. The severity and likelihood scales. The risk assessment is based on two aspects:

- The severity of consequences (S), which is based on a severity scale (Table 3) composed of 5 levels: S1 (insignificant, which corresponds to no real impact on mission or safety), S2 (minor or significant, which corresponds to the mission degradation without any impact on safety), S3 (major or severe, which corresponds to the mission failure without any impact on safety), S4 (hazardous or critical, which corresponds to safety degradation), and S5 (catastrophic, which corresponds to safety failure).
- The likelihood of occurrence (L) which is based on a likelihood scale (Table 4) composed of 5 levels: L1 (extremely improbable), L2 (improbable), L3 (remote), L4 (occasional), and L5 (frequent).

The severity and likelihood scales have been developed in a working group that takes into account the experience feedback of similar projects, the data collected from different sources, and the knowledge of each member of the multidisciplinary group.

The likelihood scale contains 5 likelihood levels associated with a recurrence period. Recurrence periods are determined according to the temporality, lifetime and technical characteristics of the CSP plant.

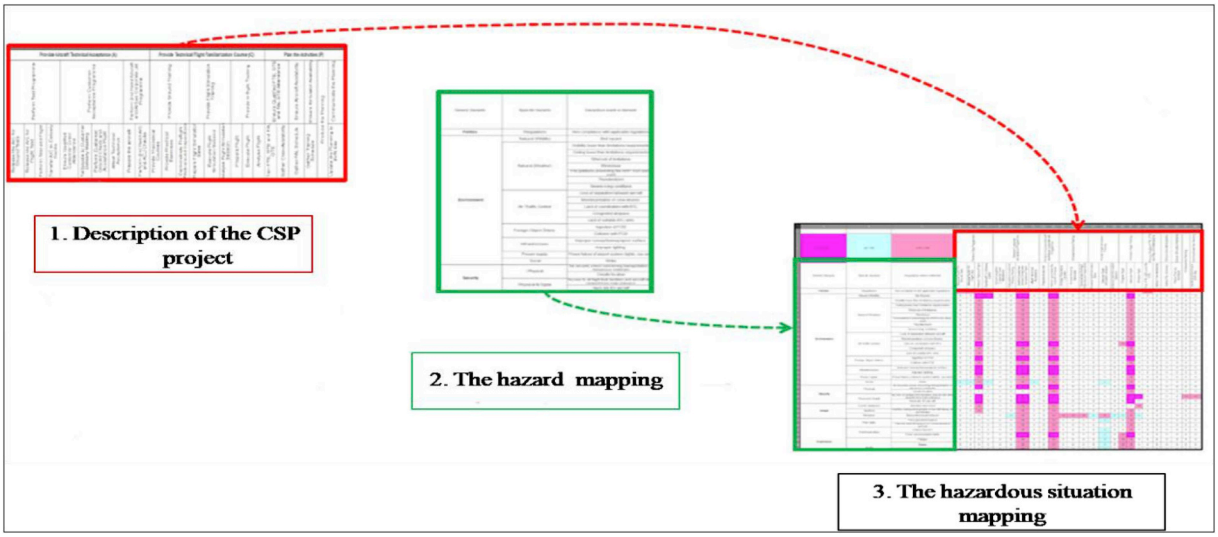


Fig. 3. The elaboration of the hazardous situation mapping.

Table 2
The interactions between the hazards and the system.

Priority Index (Ip)	Interaction Hazard/System	Decision to perform an analysis, an evaluation and treatment
Blank or 0	No interaction	
1	Strong to very strong interaction	Immediately
10	Strong to very strong interaction	Later
2	Weak to medium interaction	Afterwards

Source: Desroches et al. (2016)

Table 3
Severity scale.

Severity level	Severity name	Severity index	Description of consequences
S1	Insignificant	1	10 No impact on the system performance or safety 11 Insignificant reduction in performance without impact on activity 12 Inconsequential operational constraints 13 Temporary unavailability of structure or equipment 14 Injury on duty without work stoppage
S2	Minor	2	20 Degradation of the system performance with no impact on safety 21 Unavailability of services or equipment on the scheduled date 22 Unavailability of equipment, premises or staff less than one day 23 Injury on duty with work stoppage less than 21 days 24 Controllable pollution
S3	Major	3	30 Significant degradation or failure of the system performance with no impact on safety 31Significant performance degradation 32 Very degraded or failed activity 33 Significant operational constraints 34 Significant damage to infrastructure or goods 35 Injury on duty with work stoppage for more than 21 days
S4	Hazardous	4	40 Degradation of the system's safety or integrity 41 Severe injury or temporary disability 42 Partial destruction of infrastructure or assets 43 Significant damage to the environment 44 Temporary staff disability 45 Delay in project implementation
S5	Catastrophic	5	50 Significant degradation or failure of the system safety or its loss 51 Loss of life or disability 52 Total destruction of infrastructure or assets 53 Irreversible damage to the environment 54 Huge financial loss 55 Permanent discontinuation of the project

Table 4
Likelihood scale.

Likelihood levels	Level name	Likelihood index	Likelihood description
L1	Extremely improbable	1	Less than once per 25 years
L2	Improbable	2	Between once per 25 years and once per 5 years
L3	Remote	3	Between once per 5 years and once a year
L4	Occasional	4	Between once a year and once a month
L5	Frequent	5	More than once a month

5.3.2.2. The criticality matrix. The risk criticality represents the function of decision: $C = f_d$ (S,L). The definition domain of f_d is 25 couples (S,L) and its domain of values is {C1,C2,C3}. The criticality is the result of a decision function linked to a scale of political, social, human values, etc. (Desroches et al., 2016).

The first and most important step is to divide all the project risks into three categories according to their criticality. The criticality classes are: acceptable (C1), tolerable under control (C2), and unacceptable (C3) of respective colors: green, yellow, and red (Table 5). Each criticality class corresponds to a well-defined action.

The criticality matrix (Table 6) is a two-dimensional presentation that presents the two components of risk: likelihood *versus* severity. It allows the association of a criticality level to each severity-likelihood pair. Thus, a severity level S5 associated with a likelihood level L5 corresponds to a maximum criticality level C3.

Indeed, by defining the domain of unacceptability, we delimit the domain in which the risks must absolutely be refused and by defining the domain of tolerability or acceptability, we delimit the domain in which all the risks must be with or without a treatment.

Likelihood and severity scales and criticality matrix have been used to evaluate all the risk scenarios according to the severity of consequences and likelihood of occurrence and, then, have been prioritized by criticality. The criticality of each scenario has been determined and all scenarios have been divided into 3 categories of criticalities: C1, C2, and C3. Corrective actions have been set up in order to reduce initial risks. Once the categorization of initial risks was done, corrective actions are proposed to reduce scenarios with criticality C3 and C2. The criticality of residual risks has also been re-evaluated by according a new level of criticality that integrates the impacts of the corrective actions implemented to initial risks. (Appendix D. Scenario_GRA).

Table 5
Criticality scale.

Criticality scale.

Criticality level	Risk level	Decisions and actions
C1	Acceptable	Nothing needs to be done.
C2	Tolerable under control	No action to reduce the risk is mandatory, but a close monitoring needs to be implemented in terms of risk management.
C3	Unacceptable	The risk needs to be reduced, otherwise, the activity must be stopped partially or totally.

Source: Desroches et al. (2016)

Table 6
Criticality matrix.

Likelihood \ Severity	1	2	3	4	5
5	1	2	3	3	3
4	1	2	2	3	3
3	1	1	2	2	3
2	1	1	1	2	2
1	1	1	1	1	1

6. Results and discussions

Once the scenario GRA is elaborated by using the hazardous situation mapping, the assessment scales and the criticality matrix, we move on to data performing by using the version 2.091 of StatCart GRA developed by MAD-environment.

The application of the GRA method to the CSP project enables us to analyze the risks that impede the implementation of this project. The results are explained in details in this section. We have just analyzed the hazardous situations with priority index "1" given the serious impacts they may have on the CSP project. The scenario GRA has allowed us to identify 33 risk scenarios from the 33 hazardous situations of priority index "1".

In order to present the main results, we start with the distribution of hazardous situations by type of generic hazard, which enables us to identify the type of hazard that is likely to cause the highest number of hazardous situations and risk scenarios. We find that the political hazard creates the highest number of hazardous situations, which means that the political hazard must be taken seriously by the developers of this project. Concerning the distribution of hazardous situations by project phase (feasibility study, preparation, construction, and operation), we conclude that the preparation phase of the project contains the highest number of hazardous situations (12 hazardous situations among the 33 analyzed hazardous situations). Therefore, this phase is the most affected by the different types of generic hazards and requires the most attention.

Then, we present the distribution of risk scenarios per initial and residual criticality classes (C1, C2, and C3). We note that the risk reduction actions explained in the scenario GRA (Appendix D. Scenario_GRA) allow us to move on from 10 initial risks with C3 criticality to no residual risk with C3 criticality.

Afterwards, we present the Kiviat diagram which provides a representation of minimal, average and maximal risks per hazard and per phase while integrating at the same time criticality. According to this diagram, the risks resulting from the legal hazard have the minimum, medium and maximum risk indexes with C3 criticality (unacceptable), which means that the risks caused by the legal hazard must be taken very seriously by investors. We also note that the initial risks arising from the preparation phase have an average risk index with C3 criticality, which confirms the vulnerability of this phase.

Finally, the GRA method allows us to determine the list of top risks, such as the risk of not obtaining permission to build the CSP plant, the risk of non compliance with deadlines, the risk of failure to achieve the expected performance, the risk of insufficient access to capital, and the risk of conflicts with local residents. We explain in details the main causes of the top risks and the convenient strategies and actions that we propose to reduce them.

6.1. Distribution of risk scenarios per type of generic hazard and per project phase

We note that the political hazard is likely to cause the highest number of hazardous situations and risk scenarios (10 scenarios). The physical-chemical, financial and strategic hazards generate respectively 4, 3 and 3 risk scenarios (Table 7).

These findings are in line with the results of most studies, especially with regard to the importance of political and financial hazards in the MENA countries. However, this study emphasizes the physical-chemical hazard which is often neglected in RE projects.

The 33 hazardous situations of priority index "1", which are grouped per generic hazard type, are shown in percentages in Fig. 4. This representation shows two groups of hazards that can be classified according to their relative importance:

- Hazards with prime importance: political (30%), physical-chemical (13%), financial (9%), strategic (9%), environment (6%), management (6%), and legal (6%).
- Hazards with medium to low importance: material and equipment (3%), information system (3%), infrastructure and premises (3%), communication and crisis (3%), technological (3%), insecurity (3%), and image (3%).

It is therefore clear that the CSP project is too exposed to political hazard since the latter generates the greatest part of hazardous situations. This is quite logical given the current situation in Tunisia which is characterized by political instability following the 2010 revolution and the birth of a young democracy.

Concerning the identified hazardous situations and the scenarios analyzed per project phase (Table 8), the results show that the preparation and operation phases of the CSP project contain the highest number of

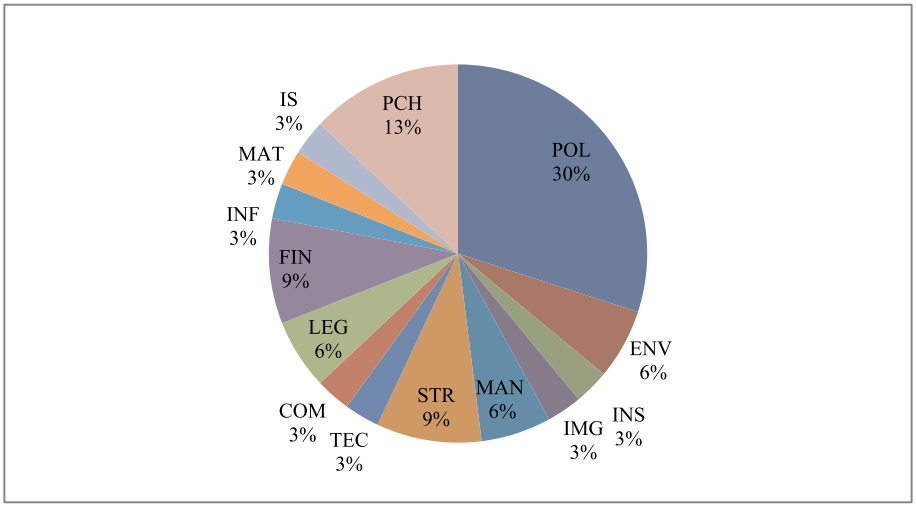


Fig. 4. Distribution of hazardous situations per generic hazard.

Table 7
Number of identified hazardous situations and analyzed scenarios per generic hazard.

Type of hazard	Index	Number of hazardous situations	Number of risk scenarios
Political	POL	10	10
Environment	ENV	2	2
Insecurity	INS	1	1
Image	IMG	1	1
Management	MAN	2	2
Strategic	STR	3	3
Technological	TEC	1	1
Communication and crises	COM	1	1
Legal	LEG	2	2
Financial	FIN	3	3
Infrastructure and premises	INF	1	1
Materials and equipment	MAT	1	1
Information system	IS	1	1
Physico-chemical	PCH	4	4

hazardous situations. The preparation phase is the phase the most exposed to the 14 generic hazards since it generates 12 hazardous situations of priority index "1". This is due to the complexity of administrative, legal and financial procedures required to have all the necessary authorizations and agreements. Indeed, this phase is decisive for the implementation of the project. Moreover, for more than 6 years, the project has been blocked in this phase without any progress towards the phase of construction. These results demonstrate the delicacy of the preparation phase and its high vulnerability to the different classes of generic hazards.

The 33 hazardous situations of priority index "1" grouped per project phase are shown in percentages in Fig. 5 in which the preparation and operation phases contain respectively 37% and 30% of all the identified hazardous situations, while the construction phase contains 24% and the feasibility study contains just 9% of all the hazardous situations.

Table 8
Number of identified hazardous situations and scenarios analyzed per phase of the project.

Phase of the project	Index	Number of hazardous situations	Number of risk scenarios
Feasibility study	A	3	3
Preparation	B	12	12
Construction	C	8	8
Operation	D	10	10

6.2. Distribution of risk scenarios per initial and residual criticality

The following tables (Tables 9 and 10) present the number of risk scenarios analyzed according to the "severity-likelihood" couple, as well as before and after the actions of reduction of initial risks presented in the scenario GRA (Appendix D. Scenario_GRA). We note that before starting these actions (Table 9), we have one initial risk with C1 criticality (acceptable), 22 initial risks with C2 criticality (tolerable under control), and 10 initial risks with C3 criticality (unacceptable).

The risk reduction actions allow us to reduce the criticality of initial risks by reducing the likelihood or the severity, or both at the same time in order to have residual risks with C1 (acceptable) or C2 (tolerable under control) criticality and no residual risk with C3 criticality (unacceptable). This is well respected in our analysis since we have 23 residual risks with C1 criticality (acceptable), 10 residual risks with C2 criticality (tolerable under control), and no residual risk with C3 criticality (unacceptable) (Table 10).

Table 9
The criticality matrix for initial risks.

Likelihood \ Severity	1	2	3	4	5
5	1		2		
4		4	7	6	
3			7	2	2
2					2
1					

33

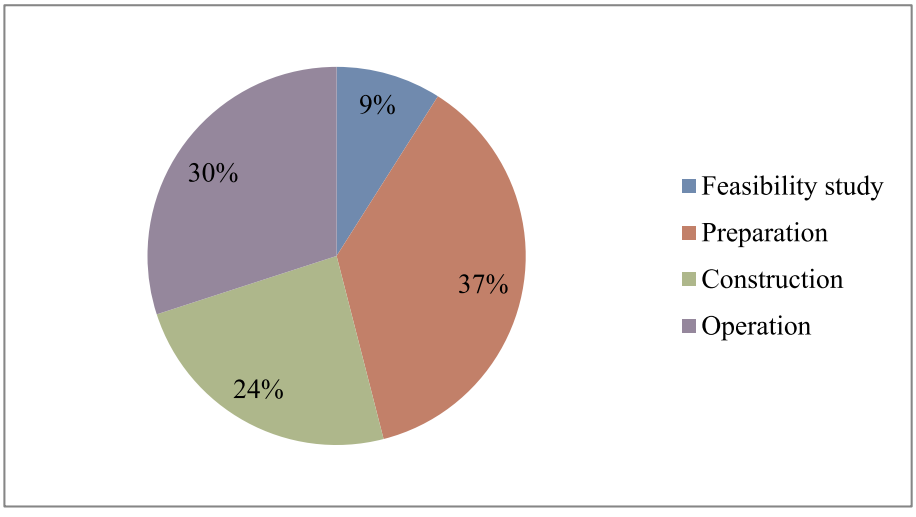


Fig. 5. Distribution of hazardous situations per project phase.

Table 10
The criticality matrix for residual risks.

Likelihood \ Severity	1	2	3	4	5
5	1				
4			2		
3	4	7	6		
2		5	5	2	
1			1		

33

6.3. Risk mapping per hazard

The Kiviat diagram provides an overview of the risks associated with the CSP project and facilitates their comparison. In fact, it provides a detailed analysis of the initial and residual risks per generic hazard or per project phase. This representation allows us to make the appropriate decisions according to the general context and the vulnerability of the project.

The axes of the diagram represent the 14 generic hazards. The minimum, average and maximum indexes of the different initial and residual risks are positioned on these axes. The Kiviat diagram also shows the three risk criticality areas (C1, C2 and C3, respectively with the colors green, yellow, and red).

According to the left-sided Kiviat diagram in Fig. 6, we notice that the initial risks descended from environmental, political, physical-chemical, financial, and legal hazards have a maximum risk index of C3 criticality. Thus, the risks arising from these types of hazards must be a priority for project developers and managers in order to avoid serious consequences.

Among these generic hazards, only the legal hazard can cause initial risks with a minimum risk index of C3 criticality. This leads us to note that the legal hazard must be taken very seriously by investors, since the risks resulting from this hazard have the minimum, medium and maximum risk indexes with C3 criticality. Thus, even if the share of risks arising from legal hazard is not very high (only 6% compared to 30% for political hazard and 13% for physical-chemical hazard), this hazard can cause risks with catastrophic and therefore unacceptable consequences for the project.

The right-sided Kiviat diagram in Fig. 6 provides an assessment of the effectiveness and magnitude of risk reduction actions. After the implementation of the initial risk reduction actions, we can make the following remarks:

- None of the residual risk indexes (minimum, average or maximum) has a C3 cirticality. Thus, the risk reduction actions implemented have succeeded in bringing all the risk indexes to C2 or C1 criticality levels. This result proves the effectiveness of the applied actions.
- The residual risks arising from political, financial, legal and environmental hazards have an average risk index of C2 criticality. Thus, the residual risks arising from these hazards are tolerable

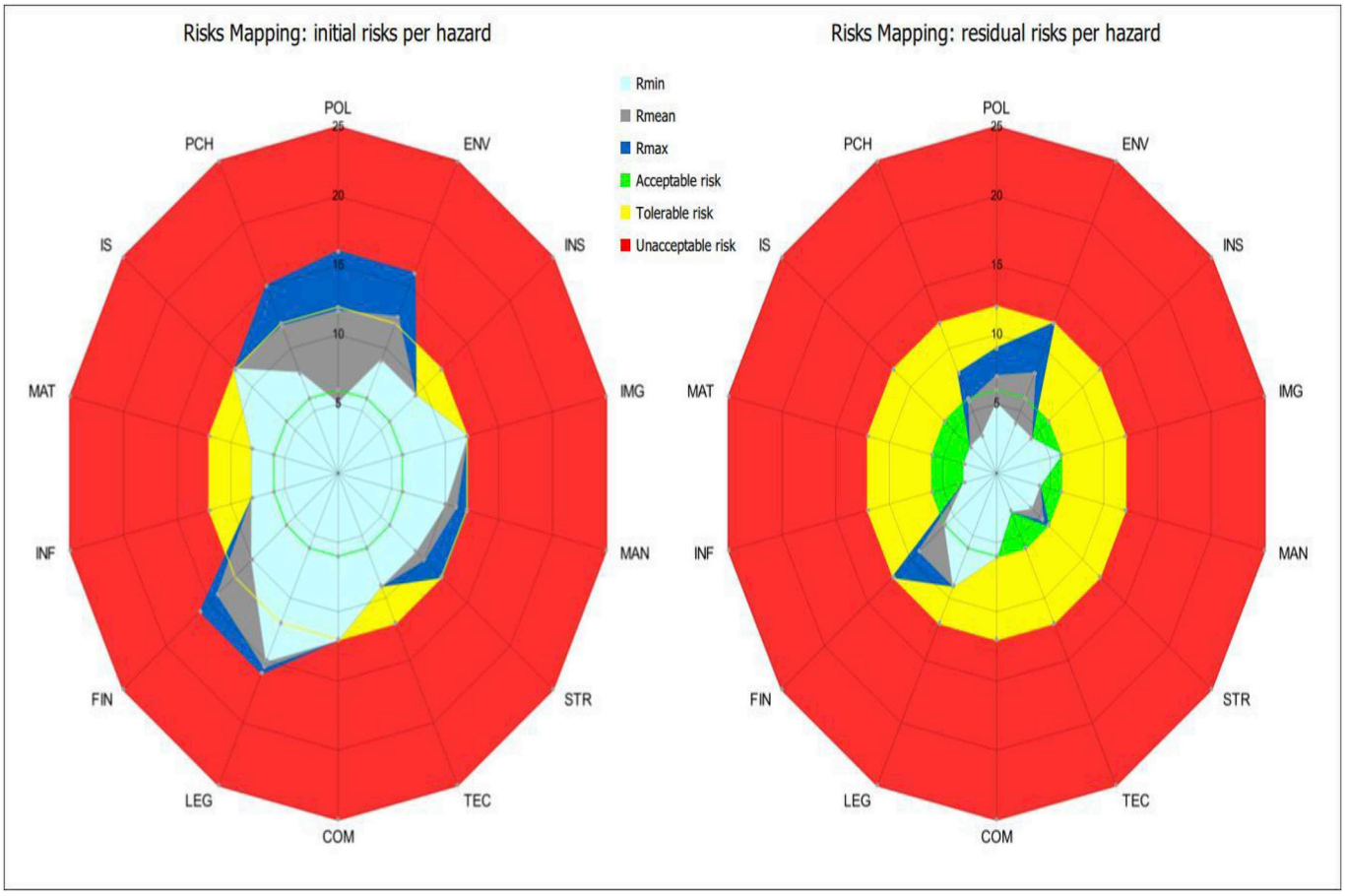


Fig. 6. Kiviat diagrams of initial and residual risks per hazard.

under control and therefore require control actions, such as insurance.
- The residual risks resulting from the legal hazard have a minimum risk index of C2 criticality. Consequently, even after the implementation of the initial risk reduction measures, the residual risks arising from the legal hazard should always be under the continuous control and monitoring by applying control measures.

6.4. Risk mapping per project phase

In the case of the analysis per project phase, the axes of the Kiviat diagram (Fig. 7) represent the 4 phases of the project (feasibility study (A), preparation (B), construction (C), and operation (D)) that have been presented and explained in the detailed analysis of the project. The axes also contain the minimum, average and maximum risk indexes corresponding to each phase of the project. The Kiviat diagram also shows the three criticality areas.

According to the left-sided Kiviat diagram in Fig. 7, we notice that the initial risks that emerge from the four phases of the project have maximum risk indexes with C3 criticality. Thus, all the four phases should be a priority for project managers in order to avoid serious consequences. In fact, among the four phases, only the initial risks arising from the preparation phase (B) have an average risk index with C3 criticality. This result confirms the vulnerability of this phase, which requires more importance than the other three phases.

After the implementation of the initial risk reduction actions (right-sided Kiviat diagram in Fig. 7), we can make the following remarks:

- None of the residual risk indexes (minimum, average or maximum) from the four phases has a C3 cirticality. Thus, the risk reduction actions implemented have succeeded in bringing all the risk indexes to criticality levels C2 or C1. This result proves the effectiveness of the applied actions.
- The residual risks arising from the preparation (B) and construction (C) phases have a residual average risk index of C2 criticality. Consequently, the residual risks arising from these phases are tolerable under control and require control actions, such as insurance. This observation leads us to stress the high vulnerability of the preparation phase to generic hazards.

6.5. List of major risks and recommendations

The GRA method allows us to determine the list of top risks. We will explain in details in this sub-section the main causes of the top risks and the convenient strategies and actions that we propose to reduce these risks.

The list of top risks identified in the present study is in line with many studies dealing with barriers to CSP investment in the MENA region. In fact, previous studies have pointed out the importance of financing barriers (Lilliestam et al., 2012), the bureaucracy and corruption (Komendantova et al., 2011), and the regulatory risk which can delay obtaining a permission (Komendantova et al., 2012). However, we find that the risk of conflicts with local residents is a serious risk that should be taken into account by developers. This result is in contrast with the analysis of Hanger et al. (2016) which shows that community acceptance is almost universal for the case of the CSP plant Noor in Morocco.

Concerning the risk of failure to achieve the expected performance because of the use of tower technology with dry cooling, this result is in contrast with the analysis of Trabelsi et al. (2016) which proves that due to the high DNI in Southern Tunisia, CSP plants with dry cooling are technically and economically competitive with the wet cooled CSP plants. Nevertheless, this research deals with parabolic trough technology and not tower technology which is used in our case study.

The major risks that can affect the CSP plant, their causes and the main actions that we propose to reduce these risks are explained as follows:

- **The risk of not obtaining a permission to build a CSP plant**

This risk results from the absence of a legal framework for the export of electricity produced from RE, in Tunisia, and the complexity of approval procedures. Moreover, the political instability since the

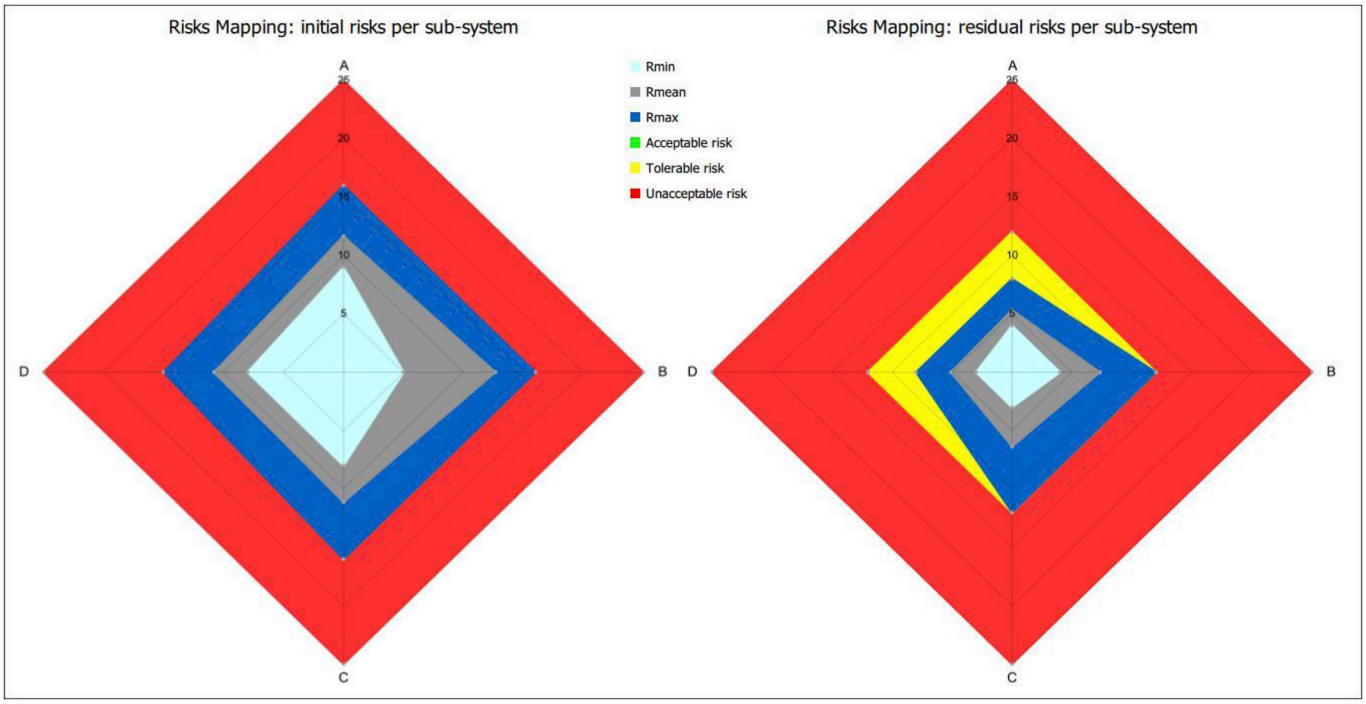


Fig. 7. Kiviat diagram for initial and residual risks per project phase.

revolution and the lack of visibility in the medium and long-term are all factors that have aggravated the situation.

In order to eliminate this legal barrier and have a suitable legal framework for this project, the project managers have initiated, since 2010, discussions with the government officials in order to develop a new regulation suitable for this project. Fortunately, after many years of waiting, a new law which authorizes the export of green electricity was approved in 2015.

- **The risk of non compliance with deadlines**

These delays can be caused mainly by bureaucracy, corruption, long and complicated administrative procedures, administrative inefficiency, delays in signing contracts, and a poor estimation of the processing time.

Moreover, uncertainty and unexpected events are linked to any large scale project so, there is always the possibility of delays. In Tunisia, this risk is more frequent due to bureaucracy and corruption, therefore, the project managers should set realistic deadlines taking into account the Tunisian context. In addition, many delays are predictable and quite common to all RE projects in the developing countries so, they can be expected and integrated into the schedule in advance. Finally, the project managers should be very proactive and have a great experience concerning large scale projects in Tunisia.

- **The risk of failure to achieve the expected performance**

This risk can be caused by the use of tower technology that is not widely used in the MENA region, as is the case for the parabolic trough technology. It can also be caused by the use of dry cooling that has not been widely experienced yet. In addition, there is a lack of experience feedback in Tunisia, since it is the first CSP project of a large size.

In order to reduce this risk, feedback from similar projects will be very useful. In fact, the CSP tower technology is used today in several countries, such as India, Spain, South Africa and the USA. Recently, the project Noor III using the same technology (CSP tower with molten salt storage) has been successfully implemented, which will help us to have a very interesting feedback from a country very similar to Tunisia. The conclusion of insurance contracts, the use of internationally renowned suppliers and the use of preventive and regular maintenance are also highly recommended.

- **The risk of insufficient access to capital**

This risk is caused by the high cost of capital, the short pay-back periods of credits and the lack of private sector participation. This risk is very common in many developing countries and can be reduced by the following measures:

- Strengthening the public private partnerships (PPP) to finance large CSP projects. In fact, PPP are an interesting solution for Tunisia, which suffers from serious budgetary constraints and does not have the means either to cover the financial losses of public enterprises or to invest in the renovation and extension of its electricity network. To ensure the success of PPP, Tunisia must put in place a strong business climate that attracts investors. This requires reducing administrative procedures to access markets, establishing a solid and stable financial system and appealing to international assistance funds, such as the Public-Private Infrastructure Advisory Facility (PPIAF).
- The implementation of feed-in tariff mechanism. This mechanism was very effective, in many countries, both in stimulating installed capacity and in developing local industry. In fact, tariffs should be set at a level that ensures the cost-effectiveness of RE projects. As a result, the market risk incurred by the project developer is inexistent and the profitability of the project depends essentially on cost control and attainment of maximum performance.
- Requesting the assistance and the support from international financial institutions and development agencies to reduce the costs of financing this project. In fact, they generally offer low-rate loans for longer periods compared to commercial banks.

- **The risk of conflicts with local residents**

This risk can be caused by the opposition to the implementation of the CSP plant and nimbyism. In order to reduce this risk, we propose the following measures:

- The use of participatory approaches which have several advantages. First of all, the participation of the various actors in the decision-making process gives some legitimacy and transparency to this decision and thus reduces the risk of non-acceptance of the decision by these same actors. In addition, the participatory approach allows decision-makers to have access to a very interesting database that concerns the preferences and expectations of different actors, especially, in terms of local employment and development of the region. In fact, it is essential to organize public consultations to collect the different issues and the main occupations of the local population and discuss these concerns with stakeholders in order to satisfy the expectations of the citizens.
- The creation of local employment is recommended. Local employees must be privileged, especially, during the construction phase which requires a high number of low-skilled workers. Indeed, the project can increase the activity of small and medium-sized local firms for the supply of the materials and the necessary equipments for the construction work, the housing and the restoration of the workers. Hence, it is also highly recommended to set up an employment commission to study the best way to promote local employment and organize short-term training for young graduates in order to acquire new skills and qualifications required for this project, while trying to achieve parity between the employment of women and men.
- The communication about the RE sector must be adequate and effective. Indeed, citizens and all the actors involved in the RE sector should have the necessary and up-to-date information on the objectives of the government, the means implemented, the regulatory and legal framework, and the achievements made. In order to ensure such communication, an updated website, discussion forums, and workshops at national and regional levels should be set up.

7. Conclusion

The application of the GRA method for the case of a CSP plant in Tunisia helped us to analyze in depth, the types of hazards that most affect the project, the phase of the project that is the most vulnerable to hazards, and the major risks that hinder its implementation.

The results of the analysis by generic hazard type show that the project is very exposed to political, physical-chemical, financial, and strategic hazards. The political hazard generates 30% of all hazardous situations, which means that the political situation in Tunisia has a negative influence on the realization of this project. The Kiviat diagram shows that, even though the legal hazard generates only 2 hazardous situations, it should be taken very seriously by investors since risks resulting from this hazard have the minimum, medium and maximum risk indexes of C3 criticality (unacceptable).

With regard to the analysis per project phase (feasibility study, preparation, construction, and operation), the two phases of preparation and operation contain the highest shares of hazardous situations, which makes them more exposed to the 14 generic hazards than the feasibility study and the construction phases. The Kiviat diagram demonstrates that, among the four phases, only the initial risks arising from the preparation phase have an average risk index of C3 criticality. This further proves the vulnerability of this phase, which requires more attention than the other three phases. In fact, this phase encompasses

all administrative procedures relating to authorizations for the construction and connection to the electricity grid and may even last for many years. In Tunisia, the case is even more serious as the project has been blocked in this phase for more than 6 years.

In addition to that, the GRA enabled us to identify the list of major risks that may affect the CSP project which are: the risk of not obtaining permission to build the CSP plant, the risk of non compliance with the deadline, the risk of failure to achieve the expected performance, the risk of insufficient access to capital, and the risk of conflicts with local residents. Then, their causes and the main actions proposed to reduce them are explained. In fact, in order to reduce these investment risks, we have proposed many measures and strategies, such as the strengthening of the public private partnership to finance this project, the use of participatory approaches, the creation of local employment, and the recourse to international financial institutions and development agencies to reduce the costs of the project.

The list of top risks identified in the present study is in line with many studies dealing with barriers to CSP investment in the MENA region which pointed out the importance of financing barriers, the bureaucracy and corruption, and the regulatory risk (Komendantova et al., 2011, 2012; Lilliestam et al., 2012).

However, we found that the risk of conflicts with local residents is a major risk that should be taken into account. This result is in contrast with the analysis of Hanger et al. (2016). We can explain this difference by the fact that the electricity produced by the CSP plant studied in this paper is intended for exports while the other cases deal with CSP plants producing electricity to strengthen the national grid and satisfy the national demand. In fact, producing electricity to be totally exported is seen by many citizens as an exploitation of national energy resources by the countries of the North.

We also found that the risk of failure to achieve the expected performance because of the use of tower technology with dry cooling is a major risk, which is in contrast with the result found by Trabelsi et al. (2016). This contrast can be explained by the fact that these authors treated parabolic trough technology, which is a more mature and used technology than tower technology that will be used for the CSP studied in this paper.

It should be noted that, over the past few years, Tunisia has begun many structural changes in the RE sector in order to de-risk and promote this sector. In fact, a new law for RE was approved in 2015. This law authorizes the exportation of electricity from RE and encourages citizens and local communities to produce green electricity. However, the distribution of electricity remains under the monopoly of STEG.

Furthermore, in order to create a favorable climate for PPP, a new law for PPP was adopted in 2015. This law is supposed to facilitate, clarify and organize PPP procedures and, above all, ensure an efficient management of the contractual risks that are frequent in this complex type of contracts. Therefore, the objective of this law is to provide a unified legislative and institutional framework that encourages private investors.

Even though Tunisia has made some progress, mainly in terms of legal framework, there are still several challenges and obstacles that slow down the development of CSP technology and RE in general as it is demonstrated by the present analysis.

However, like any research work, this study has limitations. Indeed, it is limited to a semi-quantitative study (since there are the severity and likelihood indexes). In addition, it remains general with no focus on financial risks, which are among the most serious and worrying risks for investors in the RE sector.

Although, it is very important to use the GRA method at the beginning of a project to give an overall view of the risks that may occur, this is not enough since the GRA should also accompany the whole life of the project and therefore must be revised and completed as the project progresses. The other disadvantage of this method lies in the subjectivity in risk assessment. Indeed, the estimation of the likelihood of occurrence and the severity of consequences in order to deduce the criticality remains a very subjective process.

In addition, this case study cannot be generalized to all CSP projects in Tunisia, since each CSP project remains unique and different and has specific risks, but this study remains very important and gives a general and an approximate idea of the barriers that may be encountered by future CSP investors in Tunisia.

In order to overcome these limitations, in future research studies, it will be highly recommended to complete this research by the quantitative AGR method (AGRq). The use of this method will be very interesting in the case of availability of probabilities related to risk factors. The main contribution of this method is the possibility of having a probabilistic representation of the risks and a financial evaluation of the cost/risk ratios.

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Appendices. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jenvman.2019.02.049.

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