ISTANBUL TECHNICAL UNIVERSITY ★ ENERGY INSTITUTE

RISK MANAGEMENT APPROACH AND RISK ANALYSIS IN SOLAR THERMAL ENERGY PROJECTS

M.Sc. THESIS

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Department of Energy Science and Technology

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Thesis Advisor: Prof. Dr. Üner ÇOLAK

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İSTANBUL TEKNİK ÜNİVERSİTESİ ★ ENERJİ ENSTİTÜSÜ

TERMAL GÜNEŞ ENERJİ PROJELERİNDE RİSK YÖNETİMİ YAKLAŞIMI VE RİSK ANALİZİ

YÜKSEK LİSANS TEZİ

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MAYIS 2014

Yeliz Şimşek, a **M.Sc.** student of **ITU Institute of Energy** student ID **301111051**, successfully defended the **thesis** entitled **"RISK MANAGEMENT APPROACH AND RISK ANALYSIS IN SOLAR THERMAL ENERGY PROJECTS"**, which she prepared after fulfilling the requirements specified in the associated legislations, before the jury whose signatures are below.

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Date of Submission : 1 May 2014
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To my family and close-friends,

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May 2014

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ABBREVIATIONS

App **:** Appendix
CSP **:** Concentrated Solar Power
DLR **:** German Aerospace Center
IEA **:** Internatinal Energy Agency
ITU **:** Istanbul Technical University
PMI **:** Project Management Institute
PMP **:** Project Management Professional
PMBOK **:** Project Management Book
RBS **:** Risk Breakdown Structure
ST **:** Solar Tower
TUSIAD **:** Türk Sanayici ve İşadamları Derneği
YGE **:** Yoğunlaştırılmış Güneş Enerjisi

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RISK MANAGEMENT APPROACH AND RISK ANALYSIS IN SOLAR THERMAL ENERGY PROJECTS

SUMMARY

Along with the increasing world population, fossil resources will be insufficient. Human beings are directed to the search for new energy sources. Solar energy is considered to be the most popular renewable energy solutions in recent times. Having inexhaustable, clean and sustainable features increase the attractiveness of solar energy. With the developing technology, renewable energy investment cost is reduced. Researchs for solar energy applications is accelerating and countries are creating their future energy policies in this axis.

Between the solar energy technologies, the working principle of concentrated solar power tower technology is similar to a conventional steam cycle. Because of this features, this technology can be solution for both steam and electricity generation process.

Concentrated solar power tower technology is one of the most popular technology in recent years. Workability in high temperature and pressure, having heat transfer medium with high heat capacity makes this technology advantageous.

Countries such as USA and Spain have begun to develop this technology years before and nowadays they became a pioneer of this technology. As well as csp technology developer countries, oil-rich countries of the Arabian Peninsula located in the sun-belt started to give special attention to concentrated solar power tower technology for their future energy policy.

Today not only for electricity production but also for producing potable water, fossil fuel based technologies are required in countries such as: Saudi Arabia, Qatar, the United Arab Emirates, Kuwait… To avoid drinking water problems in the future, these countries have decided to provide these needs from the solar energy. In addition to developments in the world, csp technology development in pilot scale has been also started in Turkey.

Because daily life is directly depend on energy, sustainable energy production becomes a crucial issue. As conventional energy sources, renewable energy sources have some uncertainities. For this reason, problems and uncertainties, this can occur while producing energy from sources such as solar energy, should be identified carefully.

Until a few years ago, uncertainties and risks were being handled just financially. However; with the development of the project management approach, uncertainties are started to be evaluated not only as threats but also as opportunities. At this point, the approach to project uncertainties has now changed. Thus, the importance of risk management has been understood.

Traditional risk perception has changed with the new risk approach that is more comprehensive. Based on new understanding of risk; risk is defined not only the "missing" but also the "opportunity". Risk is accepted as opportunities and threats that likely to be in the future and may affect the organization's goals.

On the basis of risk management, companies have to solve the uncertainties for project success. Due to the nature of unknowns, each project includes risks. It is important to identify the risks and to manage the risks in a best manner.

Risk management is a process including following activities: determination of uncertainty, management of controlling and monitoring of uncertainties. Detection, analysis and control of risks is important for solar technologies due to the high investment costs.

Enterprise Risk Management is a strategic business discipline that supports the achievement of an organization’s objectives by addressing the full spectrum of its risks and managing the combined impact of those risks as an interrelated risk portfolio. Project risk management is a long process starting from the conceptual design phase of the product, continuing with recent tests to be made and delivering to the customer. In addition, it includes identification of the risks that need to be resolved as a priority and required strategies for managing each of these risks.

In this thesis, risk management is defined based on the concept of PMI and the project risk analysis of ST1 power plant, an example of concentrated solar power tower technology, has performed.

In this study, risk identification and analysis has focused on the issue of concentrated solar power tower projects. Risks in the project are classified according to the following headings: conceptual design, system components design, production and supply of system components, assembly, hardware and software integration, commissioning and system tests. The risks are also categorizes as technical, social, economic and political. After risk identification and categorization, qualitative analyses of the technical risks are evaluated.

In the first part, the aim of the thesis and the literatural history of risk are explained.

In the second section, following issues are emphasized: the definition of risk in different sources, both old and new risk approaches, identification of the risk level including concepts of probability and impact, positive and negative meanings of risk, risk management approaches, the definition of enterprise risk management, risk management cycle and why risk management is necessary for the project.

In the third part, risk management methods and PMI risk management methodology have been mentioned. According to PMBok developed by PMI, project risk management is examined under six main headings: risk management planning, risk identification, qualitative risk analysis, quantitative risk analysis, risk response planning, risk monitoring and control.

In the fourth section; with ST1 project analysis, topics have been made more understandable. The current situation and the future energy scenerios of CSP have also been mentioned.

In the conclusion, outcomes of the study and potential topics for subsequent study are summarized.

TERMAL GÜNEŞ ENERJİ PROJELERİNDE RİSK YÖNETİMİ YAKLAŞIMI VE RİSK ANALİZİ

ÖZET

Artan dünya nüfusu ile birlikte fosil kaynakların yetersiz kalması olasılığı insanoğlunu yeni enerji kaynakları arayışına sürüklemektedir. Güneş enerjisi de son zamanların en gözde yenilenebilir enerji çözümü olarak değerlendirilmektedir. Tükenmeyen, temiz ve sürdürülebilir bir enerji türü olması güneş enerjisinin cazibesini artırmaktadır. Gelişen teknoloji ile birlikte yatırım maliyetlerinin düşmesine bağlı olarak, güneş enerjisi uygulamalarına yönelik çalışmalar hızlanmakta ve ülkeler gelecekteki enerji politikalarını bu eksende oluşturmaktadırlar.

Güneş enerji teknolojileri arasında, çalışma prensibi bakımından konvansiyonel buhar çevrimlerine benzerliği ile bilinen yoğunlaştırılmış güneş enerjisi teknolojileri öne çıkmaktadır. Güneş enerji teknolojilerinden olan bu termal tabanlı teknolojiler, hem elektrik üretimi hem de buharın kullanıldığı prosesler için bir çözüm olmaktadır.

Yoğunlaştırılmış sistemler arasında da sistemde bulunan kuleden esinlenerek isimlendirilmiş kule tipi yoğunlaştırılmış güneş enerji teknolojileri son yılların popüler teknolojilerinden biridir. Yüksek sıcaklık ve basınçta çalışılabilme özellikleri, ısı akışkan taşıyıcısının yüksek ısı kapasiteli bir akışkan olabilmesi gibi özelliklerinden dolayı diğer yoğunlaştırılmış güneş enerji teknolojileri arasında öne çıkmaktadır.

Amerika, İspanya gibi ülkeler öngörülü davranarak kule tipi yoğunlaştırılmış güneş enerjisi teknolojilerini geliştirmeye başlamışlar ve günümüzde de bu teknolojinin öncülerinden olmuşlardır. Teknoloji geliştiren ülkelerin yanı sıra, güneş kuşağında yer alan, Arap yarımadasındaki petrol zengini ülkeler de gelecek enerji politikalarında kule tipi yoğunlaştırılmış güneş enerjisine yer vermektedirler.

Günümüzde elektrik üretiminin yanı sıra içme suyu eldesi için de fosil kaynaklı teknolojilere bağımlı olan Suudi Arabistan, Katar, Birleşik Arap Emirlikleri, Kuveyt gibi ülkeler çok geç olmadan bu ihtiyaçlarını güneşten sağlamaya karar vermişlerdir. Böylelikle azalan fosil kaynaklarını ihraç ederek ülke ekonomisine katkıda bulunacaklar hem de ihtiyaç duydukları enerjiyi sonsuz bir kaynak olan güneşten sağlayabileceklerdir. Türkiye'de de pilot uygulama seviyesinde teknoloji geliştirme çalışmaları yapılmaktadır.

Kesinti durumunda hayatın çok ciddi sekteye uğraması konusunda ele alındığında enerji üretiminin sürdürülebilir olması çok önem taşımaktadır. Sonsuz bir kaynak, sürdürülebilir olmadığı sürece tam faydalanılan bir kaynak değildir. Konvansiyonel teknolojilerde olduğu gibi yenilenebilir enerji kaynaklarında da belirsizlikler ve sürdürülebilir olmama durumu yaşanabilir. Hatta konvansiyonel kaynaklarla kıyaslandığında kesikli kaynaklar olan yenilenebilir kaynaklardaki belirsizlikler ve sorunlar daha fazladır. İşte bu sebeple güneş enerjisi gibi kaynaklardan enerji

üretirken çıkabilecek sorunlar ve belirsizlikler çok iyi ele alınmalı ve enerjinin kesintisiz üretimi için iyi bir şekilde yönetilmelidir.

Birkaç yıl önceye kadar belirsizlikler ve riskler sadece finansal olarak ele alınıyordu. Projeyi veya şirketi sadece finansal olarak etkileyen sebepler göz önünde bulundurma anlayışı yaygındı. Fakat proje yönetim anlayışının gelişmesi ve yönetim tanımının geliştirilmesi ile birlikte, meydana çıkabilecek belirsizlikler sadece olumsuz anlamdaki tehtid kavramı değil, olumlu anlamda fırsat kavramı ile de değerlendirilmeye başlandı. İşte bu noktada artık proje belirsizliklerine yaklaşım değişmiş oldu. Böylece proje yönetim felsefesinin bir alt basamağı olan risk yönetimi de önem kazanmış oldu.

Artık geleneksel risk anlayışı yerine daha geniş kapsamlı yeni risk anlayışı almaya başlamıştır. Yeni risk anlayışına göre risk; sadece “kayıp” olarak değil, aynı zamanda “fırsat” olarak da tanımlanmaktadır. Yeni anlayışa göre risk; gelecekte olması muhtemel ve kurumun hedeflerini etkileyebilecek, tehdit ve fırsatlardır.

Risk yönetiminin temelinde, şirketlerin belirsizliklerle mücadele etme zorunluluğu yatmaktadır. Her proje, doğası gereği bilinmeyenlerden kaynaklanan riskleri her zaman barındıracaktır. Önemli olan bu riskleri tespit etmek ve riskleri en iyi şekilde yönetmektir. Risk yönetmek noktasında başvurulabilecek en güçlü yöntem, risk yönetim anlayışı ile geleceği planlamaktır.

Risk yönetimi, belirsizlik durumunun tespiti, kontrol edilebilir belirsizliklerin yönetimi ve tüm belirsizliklerin izlenmesi aktivitelerini kapsayan bir süreçtir. Yatırım maliyetleri konvansiyonel teknolojilere göre daha yüksek olan güneş enerjisi teknolojileri için risklerin tespit edilmesi, analizi ve kontrol edilmesi önemlidir. Projeye yatırım yapacak yatırımcıların riski değerlendirmesi ve başlanmış bir güneş enerjisi projesinin de kontrollü ilerleyebilmesi için risk yönetimi büyük önem arz etmektedir.

Kurumsal risk yönetimi; şirketi etkileyebilecek potansiyel olayları tanımlamak, riskleri şirketin kurumsal risk alma profiline uygun olarak yönetmek ve şirketin hedeflerine ulaşması ile ilgili olarak makul derecede güvence sağlamak amacı ile oluşturulmuş; şirketin yönetim kurulu, üst yönetimi ve tüm diğer çalışanları tarafından etkilenen ve stratejilerin belirlenmesinde kullanılan, kurumun tümünde uygulanan sistematik bir süreçtir. Proje risk yönetimi ise; uzun bir süreci kapsar. Bu süreç, ürünün kavramsal tasarım aşamasından başlayarak, son testlerin yapılıp müşteriye teslim edilmesi aşamaları da dahil olmak üzere tüm aşamaları içermektedir. Bu süreç içerisinde; hangi risklerin öncelikli olarak çözümlenmesi gerektiği sorusuna bulunan yanıtlarla beraber, bu risklerin yönetilmesi için gerekli stratejilerin ve planların uygulandığı sistematik bir yapıyı barındırır.

Bu tez kapsamında yapılan çalışmada, PMI anlayışına göre risk yönetimi tanımlanmış ve bir kule tipi yoğunlaştırılmış güneş enerjisi teknolojisini olan ST1 isimli bir örnek santralin proje başlangıcından buhar üretim safhasının tamamlanmasına kadar olan süreçlerin proje risk analizi yapılmıştır.

Bu çalışmada, kule tipi yoğunlaştırılmış güneş enerjisi projelerindeki risklerin belirlenmesi ve analiz edilmesi konusu üzerinde durulmuştur. Proje aşamalarına göre kavramsal tasarım, sistem bileşenleri tasarımı, sistem bileşenleri üretim ve satın alınması, montaj, donanım ve yazılım entegrasyonu, devreye alma ve sistem testleri başlıkları altında değerlendirme yapılmıştır. Ayrıca belirlenen riskler; teknik, sosyal, ekonomik ve politik olması durumuna göre de bir kategoriye ayrılmıştır. Sonrasında ise proje risk değerlendirmesi ve analizi kapsamında teknik kategoriye giren risklerin kalitatif analizi yapılmıştır.

Birinci bölümde; tezin amacı ve literatür araştırması anlatılmaktadır. Güneş enerji projelerinde risk yönetiminin önemi ve bu tip projelerde uygulanabilirliğini vurgulamayan tez amacı açıklamasından sonra, yine bu bölümde tezin tarihine değinen kısa bir bölüm bulunmaktadır.

Sonraki bölüm olan ikinci bölümde farklı kaynaklarda geçen risk tanımları, eski ve yeni risk yaklaşımları, risk seviyesinin belirlenmesinde rol alan olasılık ve etki kavramları, riskin pozitif ve negatif anlamları, risk yönetimi yaklaşımları, kurumsal risk yönetimi tanımı, risk yönetimi döngüsü ve risk yönetiminin projeler için neden gerekli olduğu vurgulanmış ve yenilenebilir enerji projeleri açısından risk yönetimi avantajlarından bahsedilmiştir.

Üçüncü bölümde ise; projelerde uygulanan risk yönetim metodlarından bahsedilerek, uluslararası tanınmışlığı olan Proje Yönetim Enstitüsü (Project Management Institute, PMI) tarafından hazırlanan ve kabul gören proje yönetimi anlayışının bir parçası olan risk yönetimi açıklanmıştır. Risk yönetim planının hazırlanmasında başlayarak, risklerin tanımlanması, risklerin kalitatif ve kantitatif analizleri, risk yanıt planının hazırlanması, risklerin izlenmesi ve kontrolü başlıkları altında proje risk yönetim süreçlerine değinilmiştir.

Dördüncü bölümde uygulama projesi ile birlikte konu daha da anlaşılır hale getirilmiştir. Bu bölümde örnek çalışmanın konusu olan kule tipi yoğunlaştırılmış güneş enerjisi teknolojisi çalışma prensibi ve sistem bileşenleri hakkında bilgi verilmiştir. Ayrıca gelecek için oluşturulmuş yoğunlaştırılmış güneş enerjisi teknolojisi senaryolarına değinilerek, 2020'den 2050'ye kadar elektrik üretiminde yoğunlaştırılmış güneş enerjisi teknolojilerinin payının nasıl artacağı konusu üzerinde durulmuştur.

Bunlara ek olarak; Dünya'daki ve Türkiye'deki kule tipi yoğunlaştırılmış güneş enerjisi santralleri hakkında bilgi verilmiştir. Yine dördüncü bölümde; uygulama projesi olarak, bir kule tipi yoğunlaştırılmış güneş enerjisi teknolojisi olan ST1 isimli bir örnek santral ele alınmıştır. Tespit edilen riskler; proje planında hangi aşamada olduğuna göre sınıflandırılmış (kavramsal tasarım, sistem bileşenleri tasarımı, sistem bileşenleri üretim ve satın alınması, montaj, donanım ve yazılım entegrasyonu, devreye alma ve sistem testleri) ve ayrıca belirlenen riskler; teknik, sosyal, ekonomik ve politik olması durumuna göre de bir kategoriye ayrılmıştır.

Sonrasında; belirlenen teknik riskler ele alınarak; projedeki olasılık ve etki değerleri belirlenmiştir ve risk seviyeleri hesaplanmıştır. Karşılaştırmalı olarak incelenmesi için de olasılık-etki matrisleri ve risk seviyesi grafikleri oluşturlmuştur. Sonuç olarak dördüncü bölümde; ST1 isimli örnek santralde karşılaşılabilecek riskler tespit edilmiş ve teknik risklerin kalitatif analizleri yapılarak gerekli çıktılar ortaya konulmuştur.

Sonuç bölümünde ise yapılan çalışmaya dair çıktılar özetlenerek, bir sonraki çalışmada yapılabilecek konular olan risk yanıt planlama, risk izleme ve kontrolü süreçleri üzerine durulmuştur.

Bu tez çalışması ile birlikte güneş enerji projelerinde risk yönetiminin önemi ve uygulanabilirliği kanıtlanmıştır.

1. INTRODUCTION

The former technology and technological tools used in the production was simple. Because of utilizing uncomplicated and simple technology, the solution of the problem was not complicated and did not require expertise. Along with the development of technology, innovations are being made in many areas of production. Although benefiting from technology, humankind are faced with the complexity brought by technological developments. Therefore, the complexity caused by the uncertainties and risks become inevitable. This situation constitutes a major problem for companies. In order to solve this problem companies have management plans including risk management.

Risk management starts from the product design phase and includes all stages until it is delivered to the client. It covers all about the risks: strategies and planning, acceptable risk limits identification, evaluation, response planning, monitoring and control.

Until recently, the companies evaluated risks only as financial risk. When it became apparent that uncontrolled operations cause the financial risk, operational risks have also started to be controlled.

Today mankind's energy dependence is indispensable and it is increasing with rapidly rising world population and evolving technology. Besides having a reliable energy sources, energy production technologies must be reliable. Inorder to have sustainable energy production, risks must be controlled in the energy production projects. Because of timing is also very important in energy projects, project must be finished at expected time. Inorder to get effective results in limited time, risks that may occur at each stages of the project should be kept under control.

In energy projects, risks must be well managed to be in the acceptable range and to prevent the occurrence of undesirable results. Energy projects in which risk management is neglected are both costly than estimated and energy sustainability is compromised.

Generally in energy projects, the classical approach to risk management is as follows: very time-consuming and showing the value of the project higher than expected. Whereas risk management is performed in an efficient and effective manner, it is understood that this point of view is completely wrong. The creation of well-functioning risk management system will benefit to minimize surprises, make more regular decision and planning, increase profitability and competitiveness, create of value from uncertainities.

Not only conventional energy production methods but also renewable energy projects (such as: solar, wind, hydro) have many risks. The risks of conventional energy technologies can be predicted since this technology has been developed over the years. However, renewable energy technologies contain more risk due to technological uncertainties and discontinuous sources. In order to minimize these uncertainities and risks in the renewable energy projects, the importance of risk management are mostly understood.

Based on this reality, the necessity of risk management in renewable energy projects and how to approach the implementation of project risk management in renewable energy projects is focused in this study. Besides theoretical knowledge, with a case study it is also aimed to consolidate the importance of risk management in renewable energy projects for better understanding.

1.1 Purpose of Thesis

Scope of study has focused on project risk management. Although it is applied for different sectors, generally the project risk management methodogies are similar.

The process began with the identification of risks and continues with risk analysis and prioritization of risks, and then lasts with managing the risks. Energy projects involve many different stages and the process is rather complicated. For clarity of study, some assumptions and restrictions have been made. Project management was assumed to be perfectly in all stages of the project.

The aim of this project is to emphasize the importance of risk management in renewable energy projects and to demonstrate the feasibility of the project risk management approach by analyzing the case study of an exemplary CSP Tower Steam Production Plant called ST1.

This study is initiated to investigate the following issues: risk management studies in the literature and risk management approach in the past.

In the second part, the required basic concepts have been mentioned to understand risk management clearly. In addition, risk definitions and concepts mentioned in various sources are explained. Besides, risk management described conceptually and some valuable information is given about the importance of risk management for the company and the implementation of risk management in renewable energy projects.

In the third part of the study, project risk management methodology admitted by Project Management Institute (PMI) *the world's leading not-for-profit professional membership association for the project, program and portfolio management profession*, is examined under six main headings. These six headings, risk management planning, risk identification, qualitative risk analysis, quantitative risk analysis, risk response planning, risk monitoring and control, are discussed as annotated.

Additionally, the fourth section includes case study. An exemplary CSP Tower Steam Production Plant called ST1 is examined as case study. Risk management planning and risk identification of ST1 Concentrated Solar Power (CSP) Tower Project are evaluated in this section. Besides, the classes and categories of risk assessment are specified. It is decided that risks in the project would be classified according to the following headings: conceptual design, system components design, production and supply of system components, assembly, hardware and software integration, commissioning and system tests. The risks are also categorizes as technical, social, economic and political.

Finally; in the conclusion part, the summary of the study and the topics to be studied in the following work are mentioned in this section.

1.2 Literature Review

Looking at the history of risk management it is known that studies started after World War II. Some important historical events contributed to the development of risk management. Companies gave importance to the insurance after 1955. They started to evaluate the risks of the activities and the primitive risk management methodology was created [1].

In 1967, Edward Lloyd has opened a coffee shop in London. This coffe shop was used as the exchange center of shipping informations. Therefore, Lloyd's coffee shop has evolved as the world's center of marine insurance. In addition, the financial risk management was started to be considered after insurance. In 1970, the oil crisis was also became a factor for the development of the risk management. The risk rating and risk assessment consulting services began in these years. After ten years companies were as familiar with the definitions such as ; credit risk, risk losses and market risk. In 1990s, the definition of risk management was not only “minimizing damages” but also “assessment of risks and the growth of companies”. In the twenty-first century project risk management and enterprise risk management have been understood and applied clearly [2].

In the literature there are several studies considering risk analysis in construction projects. However, risk analysis in renewable energy projects, especially for solar power plants, is very limited. In classical project risk analysis techniques, risk rating values are calculated by multiplying impact and probability values. Most existing risk analysis models, quantitative techniques, require numerical data. However, information related to risk analysis is not numerical. Referring to recent publications in the literature are as follows:

In 2011; Peter Burgherr, Petrissa Eckle and Stefan Hirschberg publised an article about risk assessment. This study was partially performed within the Collaborative Project SECURE (Security of Energy Considering its Uncertainty, Risk and Economic implications). In this study they compared severe accident risks of fossil energy chains.They are based on the historical experience contained in the comprehensive database. Comparative risk assessment provides the basis to evaluate expected risks and potential maximum credible consequences of accidents in the energy sector on an objective and factual basis. The database with its worldwide coverage over several decades was used to comprehensively analyze the historical experience of severe accidents in fossil energy chains (coal,oil,naturalgas). Generally, fatality rates are lowest for natural gas, intermediate for oil and highest for coal [3].

Additionally; after 2 years (in 2013) Peter Burgherr, Petrissa Eckle and Stefan Hirschberg publised another article about risk assessment. In this study they evaluated risk assessment of severe accident in the energy sector. In this study they also concerned the renewable energy technologies [4].

In parallel with risk analysis developments in the world, risk analysis studies has also performed in Turkey. Serhat Kucukali has studied risk assessment of river-type hydropower plants in 2011. He used fuzzy logic approach. In the study, a total of eleven classes of risk factors were determined based on the expert interviews, field studies and literature review. The risk factors are classifed as follows: site geology (geotechnical properties of the construction site), land use and permits (right to use of the land for the construction of hydropower scheme), environmental issues (impact of the scheme on ecosystem), grid connection (connection to the power system), social acceptance (impact of the scheme on local community who use the river or the surrounding lands), macroeconomic (inflation and interest rate), natural hazards (earthquake, flooding, storm and landslide), change of laws and regulations (level of political stability), terrorism (human-made disasters), access to infrastructure (road) and revenue (cash flow). A new methodology is proposed for risk rating of river-type hydropower plant projects with this research. Applicability of the proposed methodology was tested on a real case. Results of the case study showed that the proposed methodology can easily be applied by the professionals to quantify risk scores. The advantage of the this methodology is giving investors a more rational basis to make decisions and preventing overcosts and schedule changes. With the help of the fuzzy logic aproach tool, any decision maker could forecast the measure of risk of a river-type hydropower plant [5].

According to the article written by ZOU Zongxian, WEI Yang, SUN Xiaofei and ZENG Ming (2011), risk assessment of concentrating solar power has been evaluated based on fuzzy comprehensive. The study creates the risk assessment model of China’s CSP. The result of this study shows that the risk level of China’s CSP is high. In addition, this model is also applicable to risk assessment in different regions or different CSP technologies. Furthermore, this research provides some valuable investment references of CSP in China [6].

Furthermore, Edinaldo and his friends published an article in 2013. They considered Monte Carlo Method for risk assessment. They applied this method for renewable energy power generation systems. In this study, the issue they considered is economic parameters affecting investment decisions in energy sector by analyzing a grid-connected photovoltaic system of 1.575 kWp, located on the roof top of the laboratory building of the Grupo de Estudos e Desenvolvimento de Alternativas Energéticas e GEDAE, at the Universidade Federal do Pará e UFPA, Belém e Pará e Brazil, and operating since December 2007 [7].

Another article was published in this subject In 2012. Marion Hitzeroth and Andreas Megerle studied on acceptance risks and their management in energy projects. The case example analysis successfully demonstrated the importance of defining the acceptance risk as a prerequisite for its management. In its framework, components allowing to identify the risk groups to attitude changes as well as appropriate management strategies were worked out [8].

As it is seen in the literature review, the studies on risk analysis in renewable energy projects are almost performed in recent years. It is expected to increase the number of studies with further understanding of the significance of the risk analysis.

2. RISK AND RISK MANAGEMENT

2.1 Definition of Risk

Before explaining risk management methodology, risk must be defined clearly. In the past, risk is defined as “losses”. However, definition of risk has changed and not only negative but also positive meanings are considered in recent years as it can be seen in Table 2.1. Risk can be defined in various ways as a basic concept.

Table 2.1 : Risk definition differences between traditional and new perspective [9].

The Traditional View	The New Perspective
Risk is a negative factor to be controlled	Risk is an opportunity
Risk is managed in organizational silos.	Risk is managed as a whole
Risk management is the responsibility of the delegates to the lower level.	Risk management is the responsibility of top management.
The measurement of risk is subjective	Risk can be measured
Unstructured and inconsistent risk management functions can be found	Risk management for all corporate management system is established.
There is a committee that oversees the management board	The board is controlled by a risk committee

According to “Basic Concepts of Risk Management and Risk Defined” book, the most common definition of risk is the relationship between the probability of an incident’s occurrence and the consequence of that occurrence [10]. It means risk has two main components: probability (P) and consequence (C). In addition, risk can be defined as the mathematical equation:

$$R = P \times C \tag{2.1}$$

In this thesis, the definition of risk will be addressed as PMBook: *“A risk is an uncertain event or condition that, if it occurs, has a positive or negative effect on a project objective”* [11].

In addition, risk definitions mentioned in various sources are as follows [12]:

Risk as Average Results: Insurance experts expressed the risks as expected results of events. In other word, they are interested in realization of expected results.

Risk as Differences between Results: In this description, it is currently focused on minimizing the potential difference between expectations and results as much as possible.

Risk as Lost: The narrowest definition of risk is to consider the risk as lost. According to this definition, risk is defined as the occurrence of events, which have large negative effects, such as damages caused by customer, malpractice or problems resulting from natural causes or human error.

Risk as Earning Potential Factor: Risk is used as a tool to gain. The meaning of success in the business world is taking the risght risks at the right time and converting these risks to a gain.

Risk according to Related Areas: When risks are classified according to their relevant areas, several different types of risks can be categorized. Market risk, credit risk, operational risk, legal risk, information risk, environmental risk, country risk, risks related to the core business, inherent risks, control risks are some examples of different risks. The most recognized risk classification methods are grouped under four main headings: financial risks, operational risks, strategic risks and external environmental risks.

Financial Risks: The risks that arise as a result of financial position and preferences such as; credit, interest, cash, financial markets, commodity prices etc…

Operational Risks: The risks that prevent the fulfillment of an organization's core business activities. Procurement, sales, product development, knowledge management, law and brand management are some of risks in this category.

Strategic Risks: These risks are the structural risks that may prevent a company from reaching their short, medium or long-term goals. Planning, business model, business portfolio, corporate governance and market analysis are typical examples of strategic risks.

External Environmental Risks: In this category, the risks arise of the company's activities independently. However, they affect the company depending on the preferences of the company. Legal regulations, customer trends, economic and political changes, competitors and changes in the industry are examples of risk in this category.

In this thesis project, risks are classified as Technical, Economic, Social and Political according to the categories.

2.2 Risk Management

Risk management explanation in the PMBook is *"Risk management is the systematic process of identifying, analyzing and responding to project risk. It includes maximizing the probability and consequences of positive events and minimizing the probability and consequences of adverse events to project objectives"* [11].

The risk management process is changed according to the approaches. Differences are due to the risk view of the organizations. Although they have different steps, the main structures are the same in these approaches which can be seen in Figure 2.1.

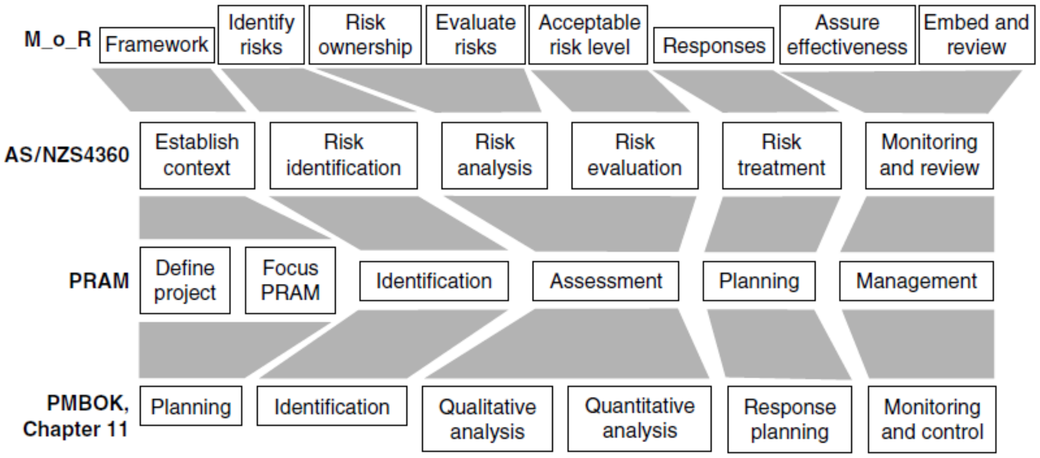


Figure 2.1 : Benchmark of project risk management standarts [13].

Risk management is important in terms of both the company and project management. The companies have recognised the importance of this issue. Then they began to embrace the concept of enterprise risk management inorder to manage risks in an integrated manner.

According to RIMS (The Risk Management Society), *"Enterprise Risk Management is a strategic business discipline that supports the achievement of an organization's objectives by addressing the full spectrum of its risks and managing the combined impact of those risks as an interrelated risk portfolio."*[14]

Additionally, risks are also important for each project of companies. Project risk management is a part of project management. Project risk management involves a long process. It starts from planning and continues to controlling of risks. In projects, risks can be divided into two groups: foreseeable and unforeseen risks. Foreseeable risks are determined and analyzed risks that could be planned. Unforeseen risks are not managed in a proactive way. Thus, it is essantial that the project team has to create a contingency plan for these risks.

The purpose of project risk management can be summarized as follows:

- To pinpoint the factors such as: scope, quality, time and cost that may affect the project
- To measure the amount of the effect of each factor
- To determine boundry line to uncontrollable factors in the project
- To alleviate the potential impact by trying the impact on risk factors that can be controlled in the project.

All standarts accept the risk management methodology as an iterative as seen in Figure 2.2 and loop process, which starts from the identification and continues with controls. In terms of monitoring and following risk management as a whole, some tools listed below can be useful in this process [16]:

- WelcomRisk
- Pertmaster
- KLCI Project Self Assessment
- RiskTrak
- Risk Radar
- Active Risk Manager
- Rational Rose

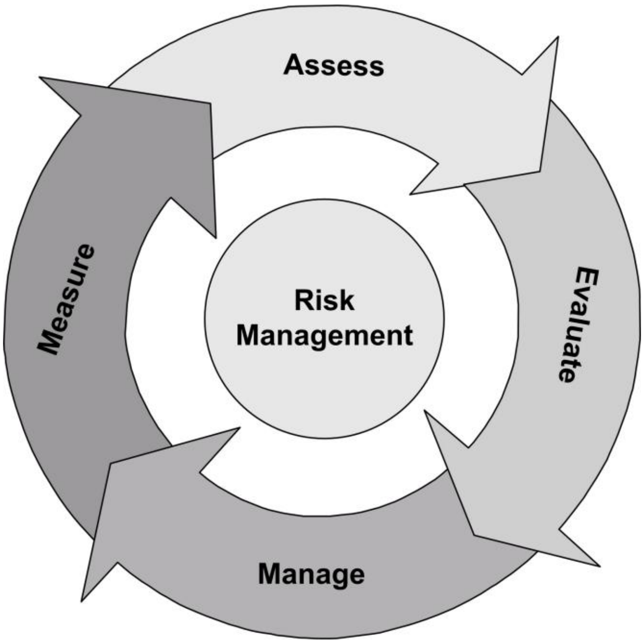


Figure 2.2 : Risk management cycle [15].

2.2.1 Why risk management is needed?

There are many benefits of risk management for companies. Inorder to ensure stability and reduce the threat, risk management becomes inevitable for companies. The necessity of risk management can be summarized under the following headings [12]:

Uninterrupted continuation of the company: Companies avoid incidents that caused huge losses. After a loss, they want to continue normal business activities with minimum delay. Despite the loss of many experienced events, by making the necessary preparations in advance risk management ensures the continuity of operations.

To minimize surprises: Uncertainties and surprises are not desirable situation for a company. Therefore; risk management is gaining importance to reduce surprises.

Reducing the cost of losses: Risk management prevents potential losses due to lower cost measures. Risks and the financial impact of risks could be controled in risk management.

Income stability: Stability is very important for the continuity of companies. Additionally, investors prefer a financially stable company. Risk management reduces unwanted and unexpected changes in annual profits and income.

Sustainable growth: Another important concept for companies is the sustainability. An effective risk management significantly contributes companies grow steadily.

Social responsibility: Investments related to measures of the environment and employee health or radical changes with environmental health concerns in business processes are within the scope of social responsibility. Risk management helps to create a good image in the public.

Compliance with regulations: Risk management is an important tools enabling compliance with legal and regulatory requirements. Activities which are against the law are organized as part of risk management.

Above listed substances for companies are also applicable for projects. Maintaining stability, sustainability, cost reduction, reducing adverse events are also desired and important subjects for projects. Therefore, risk management is critical in terms of meeting this requests for both companies and projects.

2.2.2 Risk management in renewable energy projects

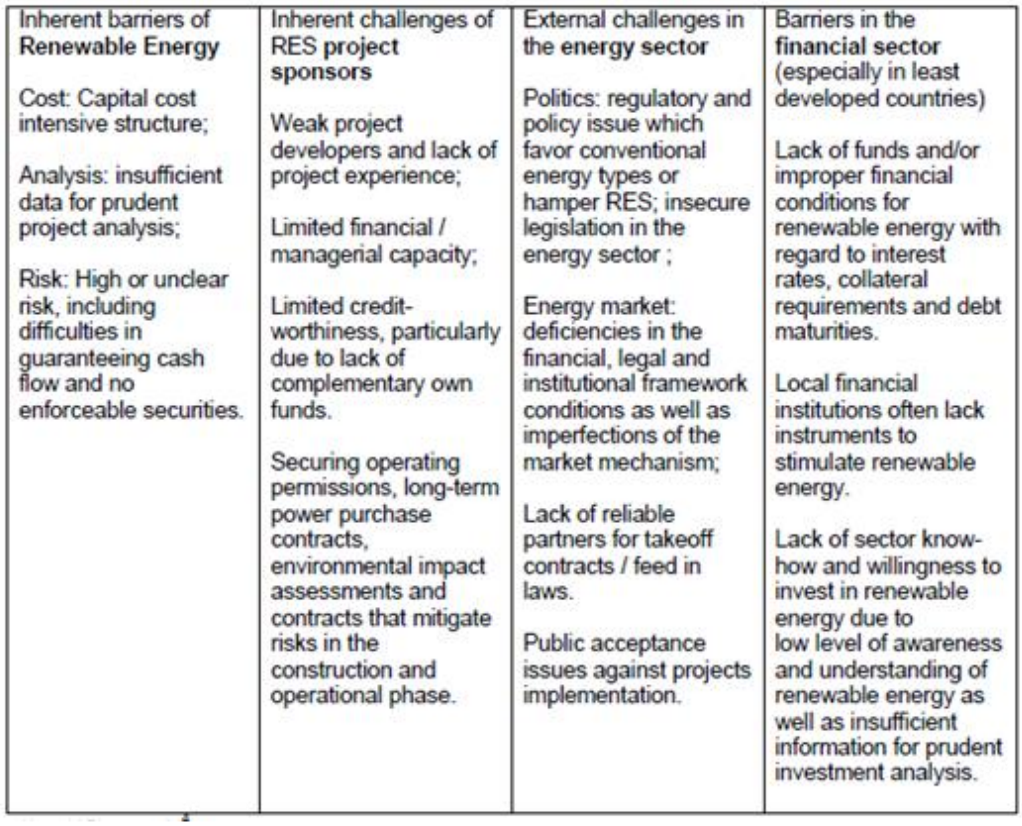
Due to the nature of life there will always be risks arising from the unknowns. The important thing is to discover and manage the uncertainities. Generally, when starting a new project, risks of the project are evaluated and the projects containing least risk are preffered. People who financed the project also consider following aspects: cost, schedule, quality, safety and environment. This is also the same in energy projects. Inorder to have sustainable, dispatchable and profitable energy projects, risk management has an important role in these cases.

In addition to conventional energy production methods, renewable energy projects (solar, wind, hydro…) have also many risks such as discontinuous sources, storage problems, etc… Inorder to minimize these uncertainities and risks in the energy projects, the importance of risk management are mostly understood. The goal of the risk management approach is to identify, evaluate and control unknowns in forthcoming projects. Standard project management approach is used for risk management in conventional energy projects. Although the similar risk methodology is applied for conventional and renewable energy projects, they differ mainly in the market and technology. Risks of renewable energy projects must be dealt with more precise. Additionally barriers and challenges of renewable energy projects can be seen in Figure 2.3.

As mentioned above, the standardized project risk management approach is applicable for all type of energy project to identify, evaluateand manage the risk.

In this thesis, PMI risk management methodology is used.

“Challenges for assessing risks table (Figure 2.4)” shows the degree of risk according to the type of technology. When solar thermal technologies are considered, many risks must be evaluated such as; having a small number of suppliers, mechanical parts failure, reflectivity error in mirrors, corrosiveness heat carrier fluid, mirrors dusting, efficiency losses, operation costs etc… These risks may vary according to the project. In the risk factors, risks related to public policy, implementation and grid integration are able to be considered as high-risk.



Inherent barriers of **Renewable Energy**	Inherent challenges of **RES project sponsors**	External challenges in the **energy sector**	Barriers in the **financial sector** (especially in least developed countries)
Cost: Capital cost intensive structure; Analysis: insufficient data for prudent project analysis; Risk: High or unclear risk, including difficulties in guaranteeing cash flow and no enforceable securities.	Weak project developers and lack of project experience; Limited financial / managerial capacity; Limited credit-worthiness, particularly due to lack of complementary own funds. Securing operating permissions, long-term power purchase contracts, environmental impact assessments and contracts that mitigate risks in the construction and operational phase.	Politics: regulatory and policy issue which favor conventional energy types or hamper RES; insecure legislation in the energy sector ; Energy market: deficiencies in the financial, legal and institutional framework conditions as well as imperfections of the market mechanism; Lack of reliable partners for takeoff contracts / feed in laws. Public acceptance issues against projects implementation.	Lack of funds and/or improper financial conditions for renewable energy with regard to interest rates, collateral requirements and debt maturities. Local financial institutions often lack instruments to stimulate renewable energy. Lack of sector know-how and willingness to invest in renewable energy due to low level of awareness and understanding of renewable energy as well as insufficient information for prudent investment analysis.

Figure 2.3 : Barriers for renewable energy systems [17].

Challenges in assessing risks associated with	**Public policy and implementation**	**Supply and demand**	**Availability of data on resource/weather pattern**	**Availability of data on technology performance**	**Grid integration**	**Operational risk**	**Intengible risk, as e.g. stakeholder opposiiton, public perception**	**Existing extent of current risk analysis in projects**
Solar thermal technologies	High	Medium (Few major players)	Low (reliable data available for large regions)	Low-High (depending on the technology maturity)	High	Medium (dispatchability, water availability)	Medium (depending on local conditions)	Low
Photovoltaic Technologies	High	Medium-High (Rapidly growing market silicon, ribbon, material, low-iron-glass, soldering paste,etc)	Low (reliable data available for large regions)	Medium (long term informaiton on device performance)	Medium	Medium (sensitivity of module reliability to manufacturing quality control)	Low-Medium (depending on scale of installation)	Medium
Biomass Technologies	High	Low	Medium	Low-High (depending on the technology maturity)	Medium	High (security of feedstock supply)	High	Medium
Wind energy	Medium (some long term regimes in place)	Medium (Rapid growth in offshore wind could be an issue)	Medium	Medium (long term information on device performance esp offshore)	High	High(True life cycle costs including overhauling costs and related logistics)	High	Medium
Geothermal Plants	Medium (some existing plants with less dependencye)	Low	High (resources insufficiently mapped)	High	Medium	High(Equipment reliability, tectonic changes)	Low	High

Figure 2.4 : Challenges for assessing risks [17].

3. PROJECT RISK MANAGEMENT METHODOLOGY

In this study "Project Risk Management" will be analyzed as mentioned in PMBok which is prepared by Project Management Institute (PMI), the world's leading non-profit association for project, program and portfolio management.

According to PMBok project risk management is examined under six main headings:

- Risk management planning
- Risk identification
- Qualitative risk analysis
- Quantitative risk analysis
- Risk response planning
- Risk monitoring and control

In the following sections these main headings (shown in Figure 3.1) are explained in details.

3.1 Risk Management Planning

Risk management planning is the first step of risk management. This proces must be considered in the beginning of the project. At this stage, risk management approach and activity plans are decided. It is very important to make planning clear and understandable for smooth implementation of risk management.

3.1.1 Inputs to risk management planning

Available project documents are utilized at the planning stage. Risk management planning inputs are project charter, organization's risk management policies, defined roles and responsibilities, stakeholder risk tolerances, template for the organization's risk management plan ans work breakdown structure. By using these materials and inputs, a successful planning can be done.

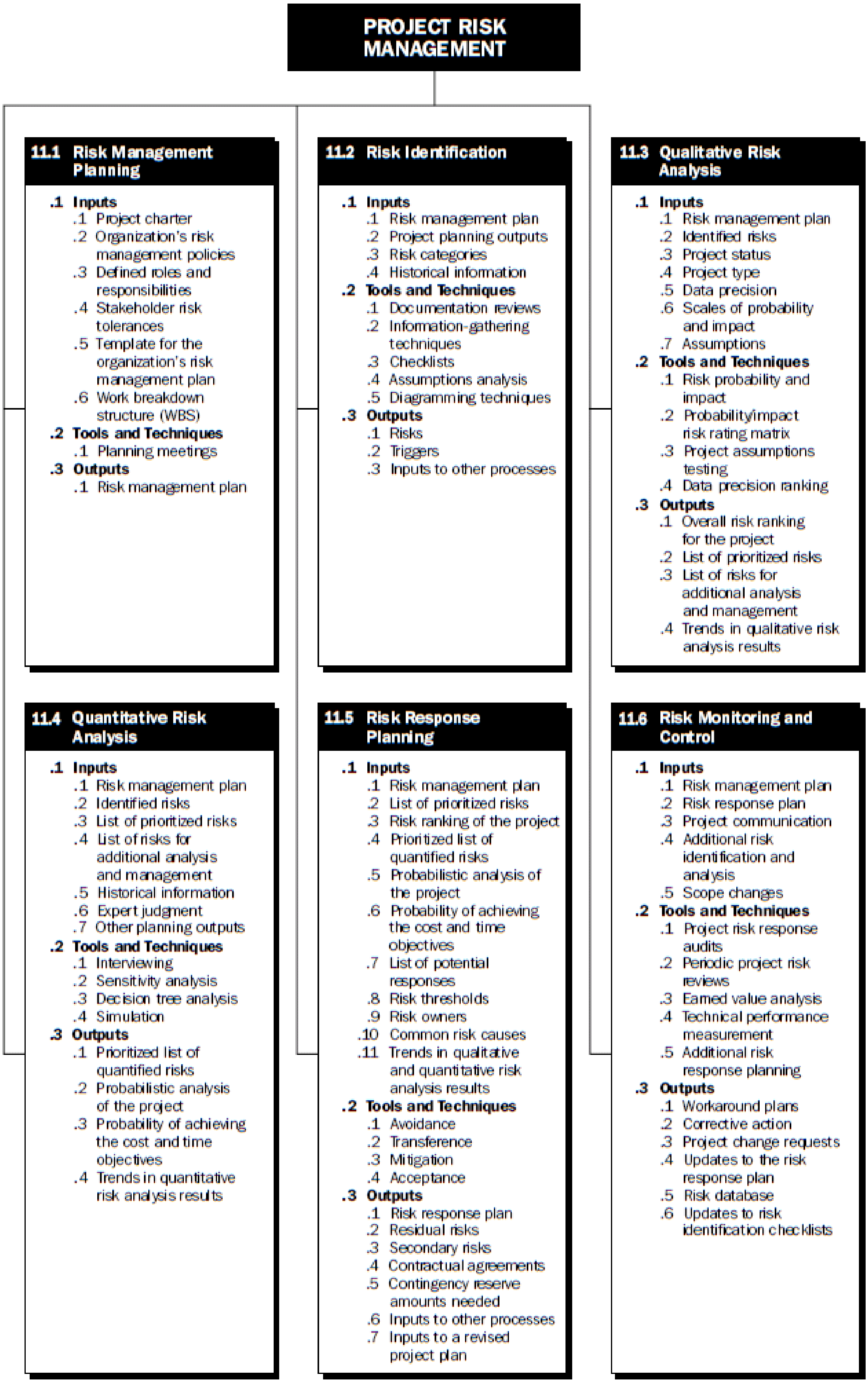


Figure 3.1 : Project risk management overview [11].

3.1.2 Tools and techniques for risk management planning

Planning meetings is the best technic to create a risk management plan. The project managers, the project team leader and responsible people for risk management are the participants of the planning meetings. These people are responsible to prepare a risk management plan by using above-mentioned inputs. In Figure 3.2, project stakeholders are seen [11].

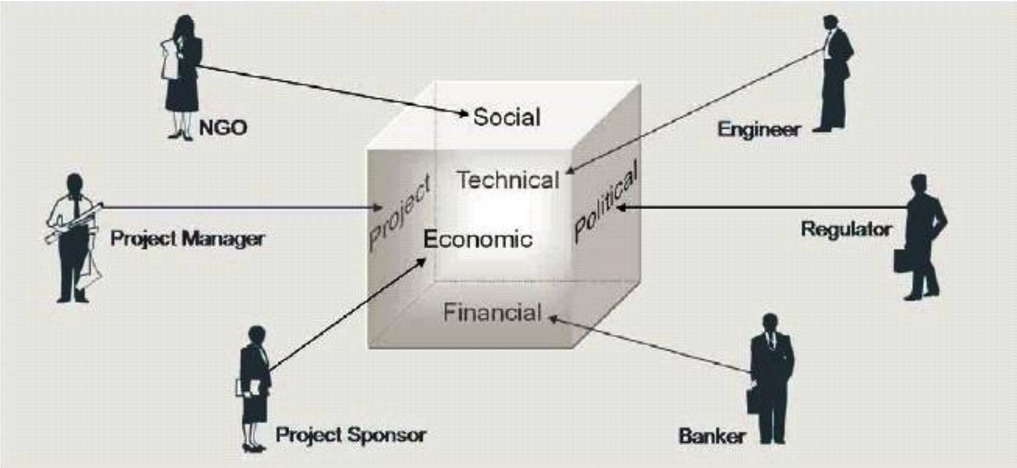


Figure 3.2 : Project stakeholders [17].

3.1.3 Outputs from risk management planning

The participants prepare the risk management plan because of several meeetings. The plan gemerally includes methodology, roles and responsibilities, budget, timing, scoring and interpretatiton, thresholds, reporting formats and tracking [11].

3.2 Risk Identification

In this stage, the risks, which affect the project, are indentified. Project team, risk management manager, sponsor, customer and supplier determine the risks. Risk assessment should be repeated at certain periods.

3.2.1 Inputs to risk identification

While identifying risks, risk management plan, project planning outputs (project charter, resourse plan, assumption lists etc…), risk categories, historical information related with project background or previous project can be used as inputs.

3.2.2 Tools and techniques for risk identification

Determination of the risks can be started with a review of documentation. In addition, information-gathering techniques are used. There are several information-gathering techniques: brainstorming, delphi technique, interviewing and SWOT analysis. Brainstorming is a common and efective way used in many stage of project management. Another method is delphi technique which is a method utilized to make predictions about the future. In delphi technique, face to face interview is not done. Forms are sent to expert people and until consensus form exchange continues. It is also possible to make an interview with expert people to identify the risks. Other proposed technique is SWOT analysis. In SWOT analysis, cases are studied as their strenghts, weaknesses, opportunities, threats [11].

Using checklists can be easy and pratic way for risk identification. Checklists are prepared from previous similar projects and historical information related with cases.

Assumptions analysis allows to examine consistency, accuracy and errors of project assumptions.

Diagramming techniques is also useful methods to identify risks. Ishikawa (fish bone) diagram, process flow charts and influence diagrams are the most widely used and effective methods in this stage.

3.2.3 Outputs from risk identification

As a result of risk identification, negative and positive risks and triggers, which affect the project, are revealed.

After the preparation of the identified risks list, the another stage inorder to manage the risks is risk analysis. More detailed information regarding the qualitative and quantitative risk analysis is discussed in the next section [11].

3.3 Qualitative Risk Analysis

Qualitative risk analysis is concerned with the impact and probability of cases. High-probability risks should be considered as priority. Probability and impact assessment are very important for the risks related to time and cost. When there is unsufficient informations for quantitative analysis, qualitative analysis can be performed.

3.3.1 Inputs to qualitative risk analysis

Inorder to perform qualitative risk analysis, risk management plan, identified risks list, project status and type, data precision, scales of probability and impact and assumptions are utilized as inputs [11].

3.3.2 Tools and techniques for qualitative risk analysis

The probability and impact are determined as low-medium-high for each of the identified risks. Then probability/impact risk rating matrix technique can be performed easily for analysis. In this matrix, acceptable and unacceptable risks appear obviously. It can be prepared as literacy and numeracy. The risk score is obtained by multipling probability and impact values. According to the risk score, matrix is coloured. As it is seen in the matrix (Figure 3.3), the high risk score are red and the colours of other scores are lighter [11].

Project assumptions testing is a good method for reviewing project assumptions. While performing qualitative risk analysis, assumptions must be reviewed and if it is necessary, new assumptions are accepted.

Data precision ranking is important in qualitative risk analysis. Qualitative data is required to be accurate and impartial. This technique provides for examination of data accuracy, quality, reliability and integrity [18].

3.3.3 Outputs from qualitative risk analysis

As a result of qualitative risk analysis, overall risk ranking for the project is carried out. Moreover; list of prioritized risks, list of risks for additional analysis and management, trends in qualitative risk analysis results are obtained [11].

After qualitative risk analysis, quantitative risk analysis can be performed.

3.4 Quantitative Risk Analysis

Quantitative risk analysis needs sufficient informations. If informations are not enough, there is no need to make a quantitative analysis. Quantitative analysis aims to express the impact and likelihood estimations in numerical values.

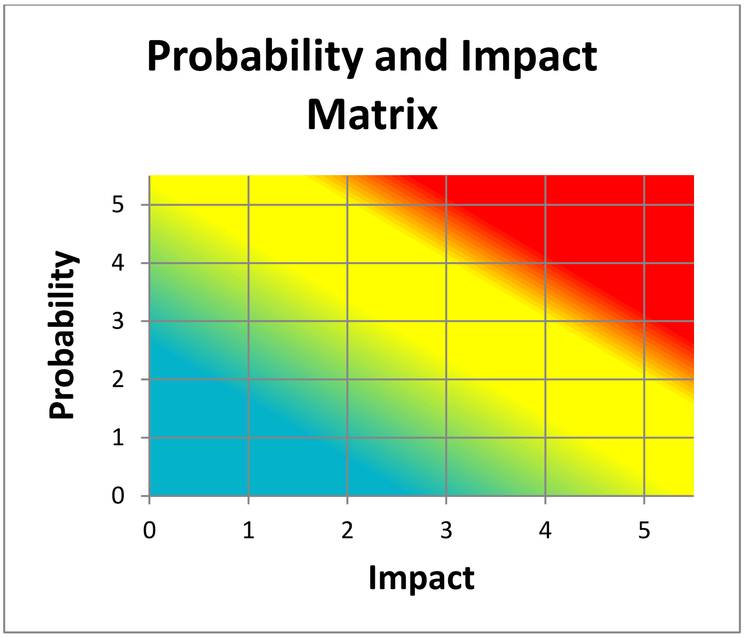


Figure 3.3 : Numerical probability and impact matrix.

3.4.1 Inputs to quantitative risk analysis

Risk management plan, outputs from qualitative risk analysis (identified risks, list of prioritized risks, list of risks for additional analysis and management), historical information, expert judgment, other planning outputs (schedules, work break down structure lists) are helpful to initialize the quantitative risk analysis [11].

3.4.2 Tools and techniques for quantitative risk analysis

Interviewing is one of methods for quantitative analysis. Project participants and experts assign numerical values (temporal and monetary) for probability and impact of risks during these interviews [11].

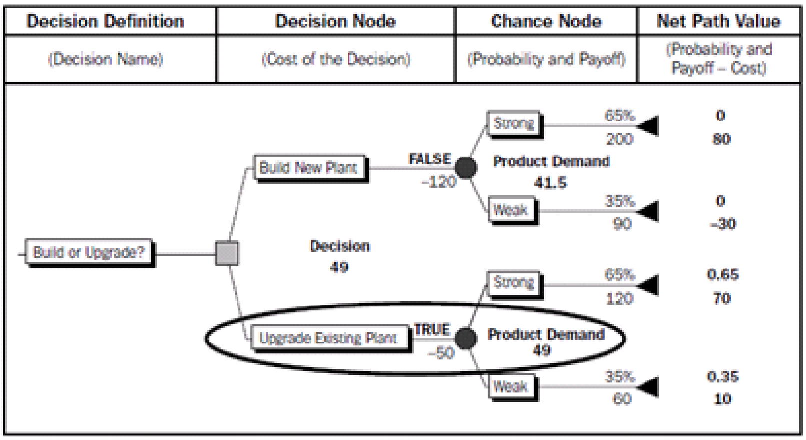


Figure 3.4 : Decision tree analysis [11].

Sensitivity analysis is used to estimate the risks that mostly affect the project. Decision tree analysis is an analysis of the uncertain cases. In decision tree analysis, it is obviously seen the results of different scenerios (example seen in the Figure 3.4).

Simulations are also used to evaluate the effects of uncertainties in the project. They generally use the Monte Carlo technique which is real and stochastic simulation.

3.4.3 Outputs from quantitative risk analysis

By the help of quantitative risk analysis; prioritized list of quantified risks is updated, probabilistic analysis of the project is done, probability of achieving the cost and time objectives are evaluated, trends in quantitative risk analysis results are obtained [11].

After risk analysis, risk response planning is the next stage in risk management.

3.5 Response Planning

In risk response planning stage, it is targeted to reduce the risks of threats and to improve the opportunities. Responsible people for each risk responses are appointed at this stage. Risk response planning must be realistic, understandable and effective in terms of risk management.

3.5.1 Inputs to response planning

When planning risk responses; risk management plan, list of prioritized risks, risk ranking of the project, prioritized list of quantified risks, probabilistic analysis of the project, probability of achieving the cost and time objectives, list of potential responses, risk thresholds, common risk causes, trends in qualitative and quantitative risk analysis results are utilized as inputs [11].

3.5.2 Tools and techniques for response planning

Avoidance, transference, mitigation and acceptance are the most widely used techniques for risk response planning. The first three ones are usually used for threats (negative risks) but acceptance is usually used for both threats and opportunities (positive risks). Changing the project plan to eliminate the influence of risk is a sample of avoidance. Transference reduce the risk effect but does not eliminate the risk totally. Thus, transferred cases or stage must be choosen carefully.

Mitigation refers to reducing the likelihood and/or effect of a risk. In some cases all of the threats can not be destroyed and in these cases acceptance is a technique for risk response.

Additional budget, time and source can be shared to this kind of risks [11].

3.5.3 Outputs from response planning

As a risk response planning outputs, lists related with risk management are updated. Residual and secondary risks, needed contingency reserve amounts are determined. The project plan is also revised as a whole after risk reponse planning.

In risk management, monitoring and control is also important as well as planning. Next section gives brief information about risk monitoring and control [11].

3.6 Risk Monitoring and Control

Inorder to manage the risks succesfully, monitoring and control stage play an important role. This stage refers to monitoring and keeping existing risks under control and discovering new project risks.

Additionally, in this process the validity of project assumptions are checked. As a result of monitoring and control, records kept at a certain periods.

3.6.1 Inputs to risk monitoring and control

As mentioned previous steps, risk monitoring and control stage also has some inputs such as: risk management plan, risk response plan, project communication plan, additional risk identification and analysis and scope changes plan.

These documents and plans supports monitoring and control step [11].

3.6.2 Tools and techniques for risk monitoring and control

Some tools and techniques that can be used for risk monitoring and control are as follows: re-evaluation of risks, risk audits, variance and trend analysis, technical performance measurement, reserve analysis, status meetings [18].

Risk audits can be performed by meetings. Besides, performance measurement techniques are compared with time schedule.

3.6.3 Outputs from risk monitoring and control

At the end of this stage; project management plan, related project documents, risk lists, organizational process assets, project change requests (taking corrective and preventive actions into account) are updated [11].

4. CASE STUDY

Concentrated Solar Power (CSP) Tower System is one of the most promising solar thermal power generating systems. They are non-polluting and long lasting power systems. The system utilizes a large number of solar concentrating mirrors called heliostats which focus the solar energy.

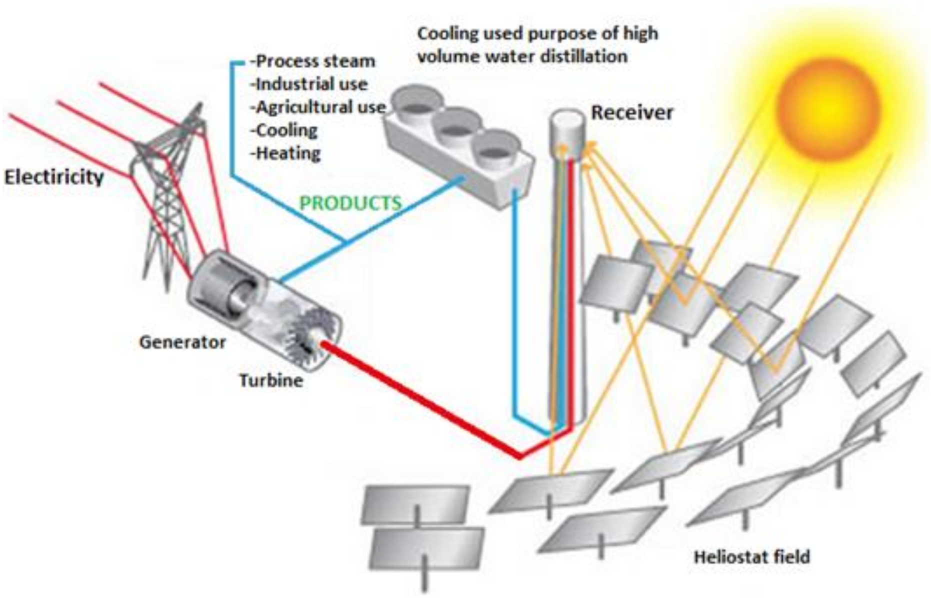


Figure 4.1 : CSP tower system scheme [19].

The system generally consists of the following components (shown in Figure 4.1):

- Heliostat Field
- Tower
- Solar receiver
- Turbine-generator

The working principle (shown in Figure 4.2) of the system is explained as follows: The heliostats reflect the incoming solar rays towards the heat receiver mounted on top of a tower.

The receiver then turns the water into super-heated steam, which in turn is transformed into electricity by a standard electric generator, connected directly to a steam turbine.

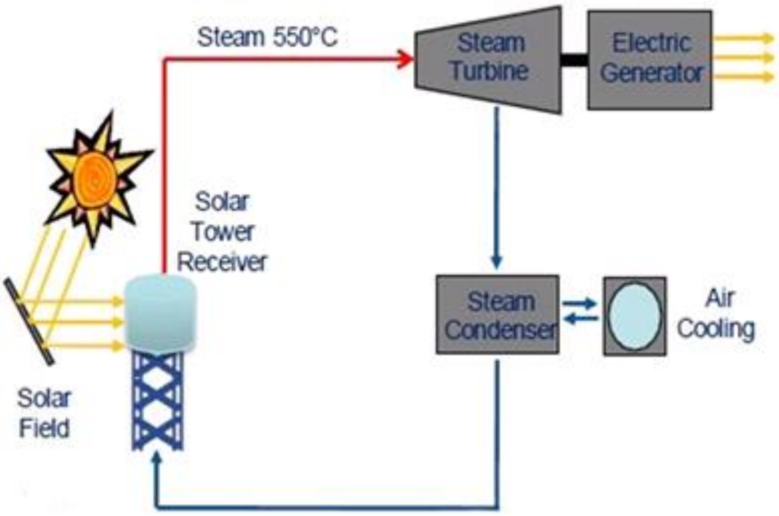


Figure 4.2 : Working principle of CSP tower [20].

Heliostats are highly polished glass mirrors, which are specialized for the operation. They have a high reflection ratio and can track the Sun in dual axis.

The reflected solar radiation is kept constantly focused on the receiver by a tracking device system that continuously turns the heliostats and directs them to the receiver, following the sun along its annual and daily path. The receiver is a very important stage for optimum efficiency design. The system is simple and it is based on keeping receiver losses to a minimum and a high rate of efficiency energy collection.

The receiver absorbs the energy being reflected from the heliostats and transfers them accordingly in producing the energy to create the super-heated steam (SHS).

The systems' electrical output is directly proportional to the intensity of the solar radiation, the size of the heliostat field, its optical and general efficiency and the efficiency of the system as a whole, including the receiver, the steam generator and the electric generator.

Solar radiation, an emission-free and inexhaustible supply of energy, it is the most abundant of all known energy sources in the world. Utilizing solar technology and other forms of renewable energy helps to reduce the reliance on fossil fuels for energy production, thus directly reducing CO_2 emissions, which contribute to climate change and global warming.

According to “Energy Technology Perspectives 2008 report” of International Energy Agency (IEA), CSP will be one of the pioneer technology that will help to reduce CO_2 emissions. In this report some scenarios (shown in Figure 4.3) related to CSP have been mentioned. In accordance with the ETP BLUE Map scenario, it is expected that CSP will contribute 5% of the annual global electricity production in 2050.

Additionally, in the Advanced scenario of CSP Global Outlook 2009, estimated by, the European Solar Thermal Electricity Association, the IEA SolarPACES programme and Greenpeace, global CSP capacity wil reach at 1500 GW in 2050. Another estimation has done by the German Aerospace Center (DLR) for the renewable energy potential in the Middle East/North Africa region. According to this study, it is estimated that CSP plants would produce nearly half of the region’s electrical production, from a total capacity of 390 GW [15].

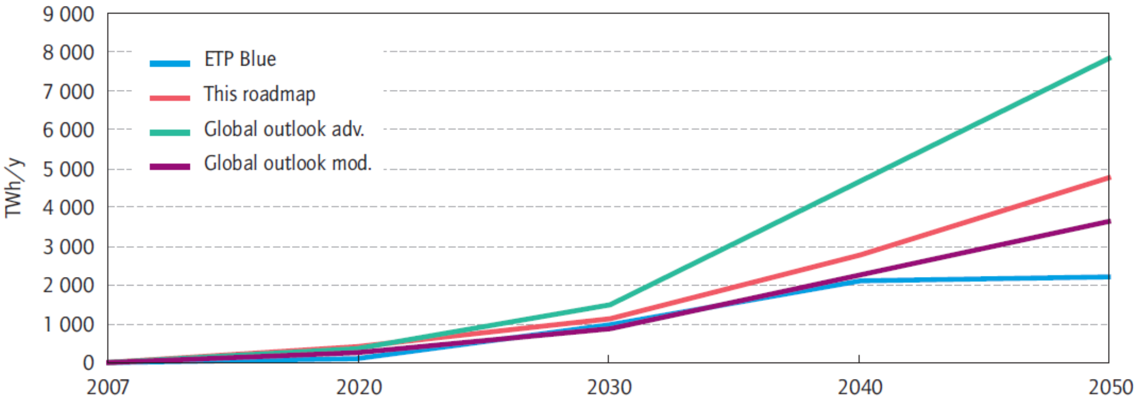


Figure 4.3 : Growth of CSP production under four scenarios (TWh/y)[21].

Furthermore; in this report, electricity production around the world will increase significantly by 2050 shown in Figure 4.3. For example, Australia, Central Asia countries, Chile, India, Mexico, South Africa will reach 40% electricity as shares of total electricity consumption from CSP plants. Additionally, electricity from CSP plants as shares of total electricity consumption table can be seen in Table 4.1[21].

When considering regional rise in CSP; North America, Africa, India are estimated three regions with the maximum CSP electricity production by 2050 (shown in

Figure 4.4). And the least three CSP production is expected in EU countries+Turkey, Pacific and China [21].

Table 4.1 : Electricity from CSP plants as shares of total electricity consumption [21].

Countries	2020	2030	2040	2050
Australia, Central Asia (including Afghanistan, Kazakhstan, Kyrgyzstan, Pakistan, Tajikistan, Turkmenistan, and Uzbekistan), Chile, India (Gujarat, Rajasthan), Mexico, Middle East, North Africa, Peru, South Africa, United States (Southwest)	5%	12%	30%	40%
United States	3%	6%	15%	20%
Europe, Turkey	3%	6%	10%	15%
Africa, Argentina, Brazil, India	1%	5%	8%	15%
Indonesia	0.5%	1.5%	3%	7%
China, Russia	0.5%	1.5%	3%	4%

By consider these scenarios, countries such as; USA, Spain, Germany and China have acted actively and they have already begun to develop CSP Tower technology in advance.

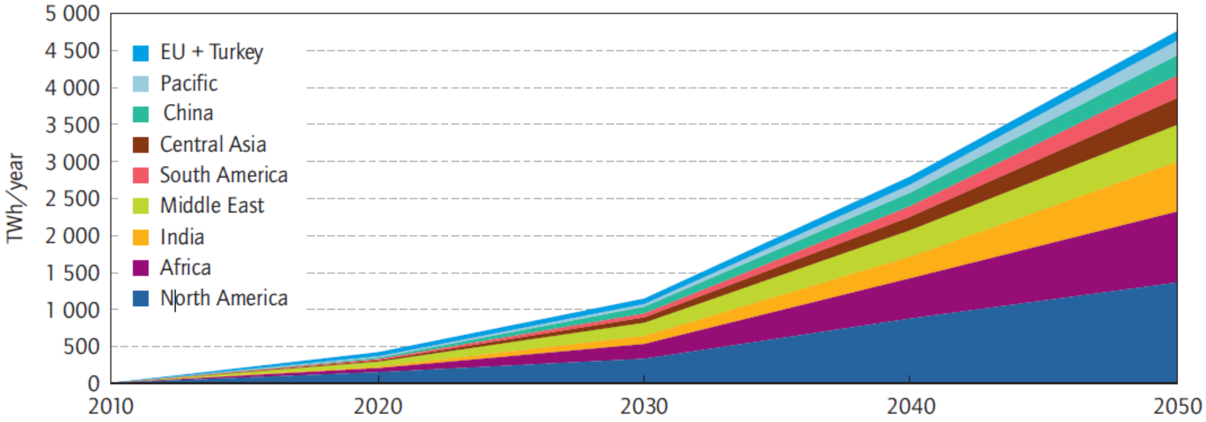


Figure 4.4 : Growth of CSP production by region (TWh/y) [21].

As CSP Tower Plants coud be installed in large power capacity, they could also be erected to develop these technology components. There are a few companies working in this field. USA and Spain are one of the pioneers in this technology. The list of operational CSP Tower Power Stations can be seen in Table 4.2. USA has already finished 370-MW Ivanpah project (shown in Figure 4.5) in California with water-steam at 565°C and 29% efficiency [16].

Current installed CSP Tower capacity in Spain includes the PS10, PS20 (Figure 4.6) and Gemasolar plants. The capacity of PS10 and PS20 are 11 MW and 20 MW, respectively.

Table 4.2 : Operational CSP tower power stations [22].

Capasity (MW)	Name	Country	Location
392	Ivanpah Solar Power Facility	USA	San Bernardino County, California
20	PS20 solar power tower	Spain	Seville
19,9	Gemasolar	Spain	Fuentes de Andalucia (Seville)
11	PS10 solar power tower	Spain	Seville
10	Delingha Solar Power Plant	China	Delingha
5	Sierra SunTower	USA	Lancaster, California
2,5	Acme Solar Thermal Tower	India	India
1,5	Jülich Solar Tower	Germany	Jülich
1,5	Beijing Badaling Solar Tower	China	Beijing
1	Yanqing Solar Power Station	China	Yanqing County
10	Crescent Dunes Solar Energy Project	USA	Nye County, Nevada

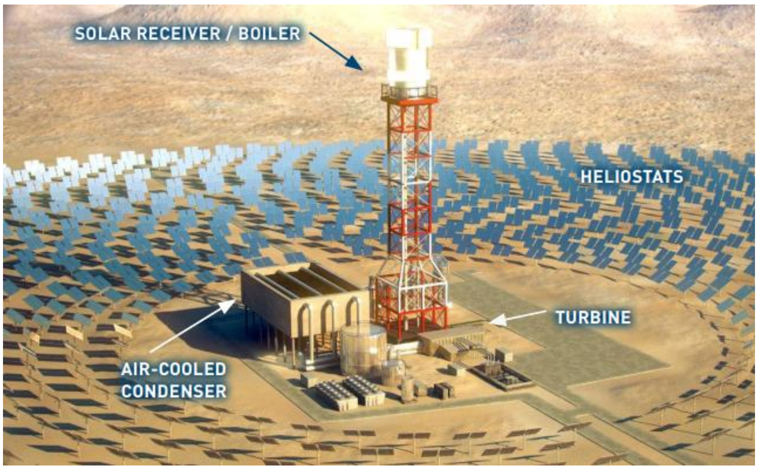


Figure 4.5 : Ivanpah project in California [23].

Figure 4.6 : PS10 and PS 20, Spain [24].

Gemasolar (Figure 4.7) is also important project for Spain, 19-MW molten salt-based ST plant with a 15-hour molten salt storage sytem [25].

,

Figure 4.7 : Gemasolar, Spain [26].

In addition; some oil-rich countries in the Arabian Peninsula such as: Saudi Arabia, Qatar, the United Arab Emirates and Kuwait, have also started to work on this issue due to the progressive reduction of fossil resources. Saudi Arabia has published the targeted electricity production until 2023 from solar thermal energy as 35 GW [27].

Likewise, Qatar and Kuwait also announced that they would provide incentives for the solar electricity production.

This technology is important not only for the production of electricity but also for the production of drinking (sea water desalination). For this reason, Arabic countries are aiming to increase the share of solar thermal energy in their future energy policies.

Figure 4.8 : Mersin project, Turkey [20].

In Turkey, studies in this field are carried out with a pilot project established in Mersin. The first project has completed in Toroslar/Mersin in 2013. With this project steam is produced by concentrating solar energy. Power block integration will be completed in the third quarter of 2014. Mersin Project's capacity is $5MW_{th}$ (Figure 4.8). The output of the system is super heated steam. The field (Figure 4.9) has 508 heliostats. Each heliostats (Figure 4.10) track the sun in two axes by the help of a special control card.

Figure 4.9 : Mersin project, Turkey [20].

The components of the system are designed in a Lego type construction kit in order to be transported and reassembled easily and quickly to any given location around the world, thus reducing time and labor costs.

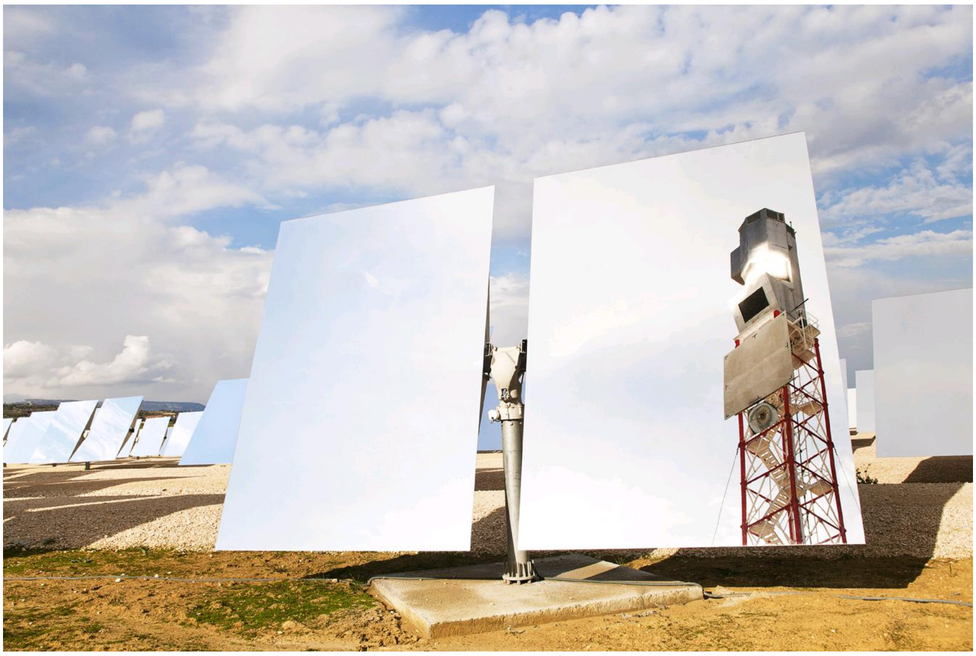


Figure 4.10 : Heliostat in Mersin project [20].

In addition, all communications are done by Secure Wireless System in Mersin project. Because of this feature, Mersin project (Figure 4.11) is the world's first CSP Tower Plant including wireless communication system.

Figure 4.11 : Mersin field [20].

In the following section, project risk analysis has been performed for an exemplary CSP Tower Steam Production Plant called ST1. Project risk analysis is evaluated until steam production phase.

During this study, risks related to power block unit (turbine, generator, etc..) and electricity production process have not been considered.

4.1 Risk Management Planning of ST1 Project

In accordance with the prepared project plan (given in App.A) for ST1 CSP Tower plant, project process and schedule have determined. It is assumed that after several meetings, responsibilities have been assigned; probability and impact assessment forms have been prepared.

It is decided that risks in the project would be classified according to the following headings:

- Conceptual design
- System components design
- Production and supply of system components
- Assembly
- Hardware and software integration
- Commissioning and system tests

It is also decided to categorize risks as technical, social, economic and political. The templates of documents used for risk analysis have been created. It is additionally assumed that the planning team has decided the analysis to be performed within the scope of risk analysis.

The following draft tables are documentations prepared to keep risk analysis in an orderly manner.

In “Risk Identification Table (Figure 4.12)”, risks are assessed by categories and according to the stage of the project phase.

After risk identification table, in order to perform qualitative risk analysis “Risk Probability-Impact-Risk Level table (Figure 4.13)” is used to have a numerical result.

			In which phase(s) does the risk cause concern?					
Number	**Category**	**Risk**	**Conceptual Design**	**System Components Design**	**Production and Supply of System Components**	**Assembly**	**Hardware and Software Integration**	**Commisioning and System Test**
1	Technical							
2	Social							
3	Economic							
4	Political							

Figure 4.12 : Risk identification table draft.

			In which phase(s) does the risk cause concern?							
Number	**Technical Risks**	**Conceptual Design**	**System Components Design**	**Production and Supply of System Components**	**Assembly**	**Hardware and Software Integration**	**Commisioning and System Test**	**Probability**	**Impact**	**Risk Level**
1										
2										
3										
4										

Figure 4.13 : Risk probability-impact-risk level table of technical risks.

5 (Very High)	5 (Low)	10 (Medium)	15 (High)	20 (High)	25 (Unexaptable)
4 (High)	4 (Low)	8 (Medium)	12 (Medium)	16 (High)	20 (High)
3 (Medium)	3 (Low)	6 (Low)	9 (Medium)	12 (Medium)	15 (High)
2 (Low)	2 (Low)	4 (Low)	6 (Low)	8 (Medium)	10 (Medium)
1 (Very Low)	1 (Insignificant)	2 (Low)	3 (Low)	4 (Low)	5 (Low)
Probability	**1 (Very Low)**	**2 (Low)**	**3 (Medium)**	**4 (High)**	**5 (Very High)**
Risk	**Impact**				

Figure 4.14 : Risk matrix.

Furthermore; in the risk management planning stage, risk matrix (Figure 4.14) is also determined in accordance with probability and impact. By the help of this matrix, risk level could be identified by numerically (form 1 to 25) and severity (low, medium and high).

Moreover, probability and impact matrix draft (Figure 4.15) is perpared to evaluate risks in the qualitative risk analysis

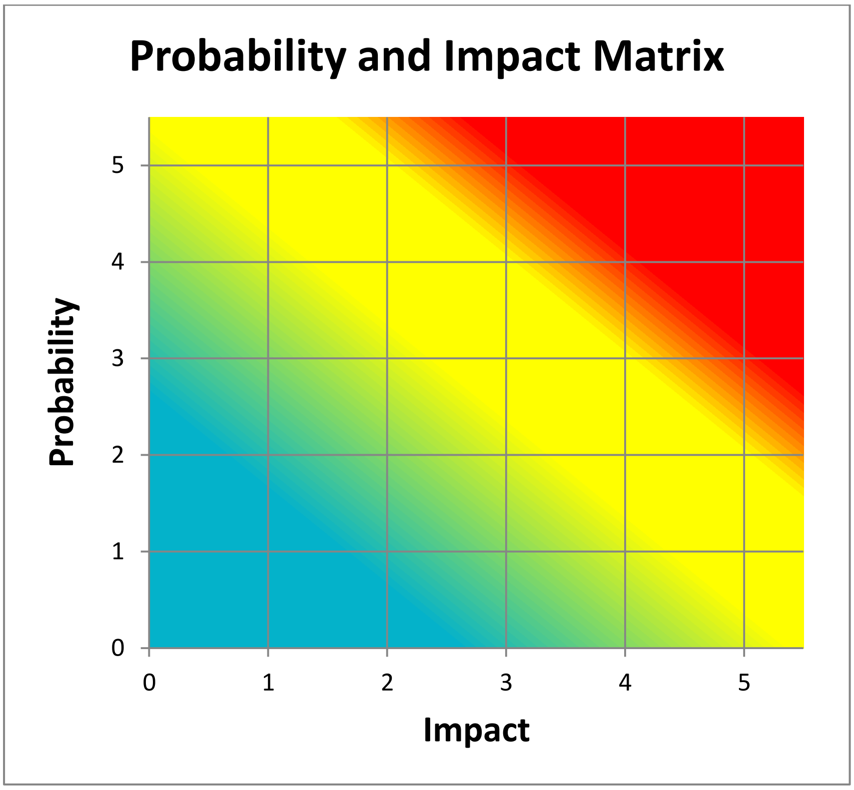


Figure 4.15 : Probability and impact matrix table.

Consequently, in this stage project risk analysis is completed and required draft documents are created for project risk analysis. After that, risk identification is performed for ST1 project.

4.2 Risk Identification of ST1 Project

It is assumed that project team firstly determine the risks at the regular meetings by reviewing of the following documents: risk management plan, resourse plan, assumption lists, project charter etc... Then they apply suitable tools and techniques for risk identification: brainstorming, delphi technique, interviewing and SWOT analysis.

The most widely used method is brainstorming for this project. Team members identify the risks by brainstorming in the meetings. In this stage risk breakdown structure (RBS) is also formed (given in App. D).

During ST1 project risk identification (given in App. C.); risks are categorized according to the project stages: conceptual design, system components design, production and supply of system components, assembly, hardware and software integration, commisioning and system tests.

As a result, ninety-one (91) risks have been found.

In Figure 4.16 shows “Risk shares according to project stages (Figure 4.16)”.

Thus, six percent (6%) of the identified risks are found in conceptual design stage of the project; seven percent (7%) of identified risks are in the system component design phase; twenty-one percent (21%) of identified risks are in the production and supply of system componens stage; twenty-six percent (26%) of identified risks are in the stage of assembly; again seven percent (7%) of identified risks are in the hardware and software integration phase; and thirty-three percent (33%) of identified risks are found in commisioning and system test stages.

The largest number risks (thirty-five risks) are determined in the “commisioning” stage of the project.

The second and third risky part of the project are “assembly” (twenty- seven risks) and “production and supply of system components” (twenty-two risks) stages.

The stages containing the least risk are as follows: “conceptual design” (six risks), “system components design” (seven risks) and “hardware and software integration” (seven risks).

These risks are also categorized as technical, social, economic and political. The number of technical, social, economic and political risks are sixty- two (62), thirteen (13), thirteen (13) and three (3) in this order.

During the risk identification stage, risk breakdown structure (Table 4.3) is also created. In the Table 4.3, risk breakdown structure is shown up to the second level. Additionally, full risk breakdown structure could be found in Appendix D.

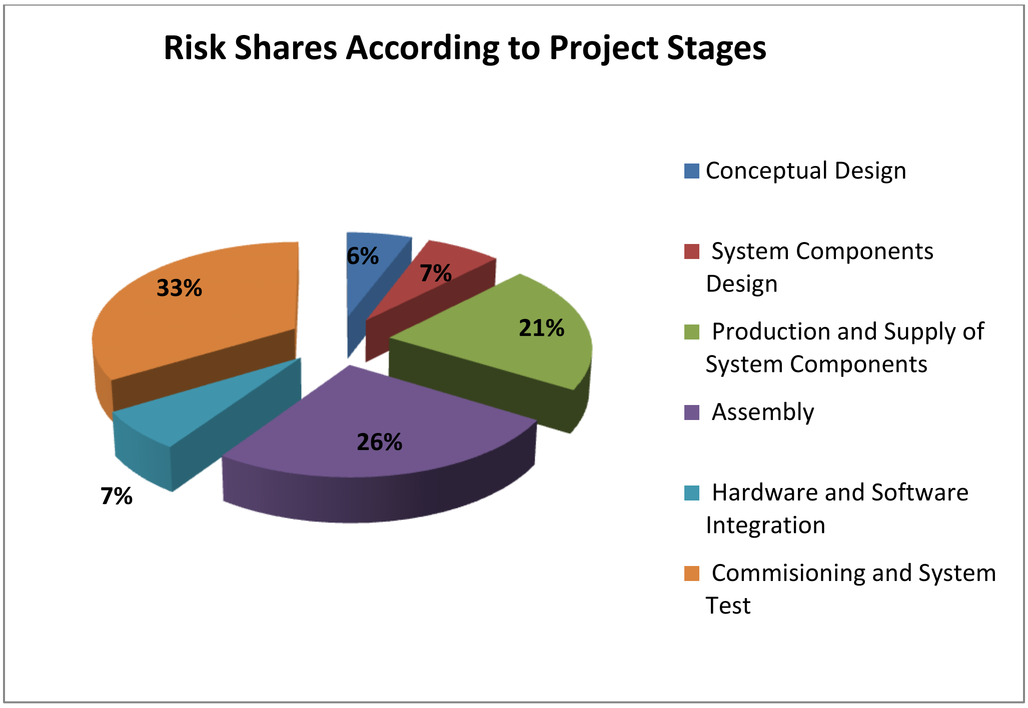


Figure 4.16 : Risk shares according to project stages.

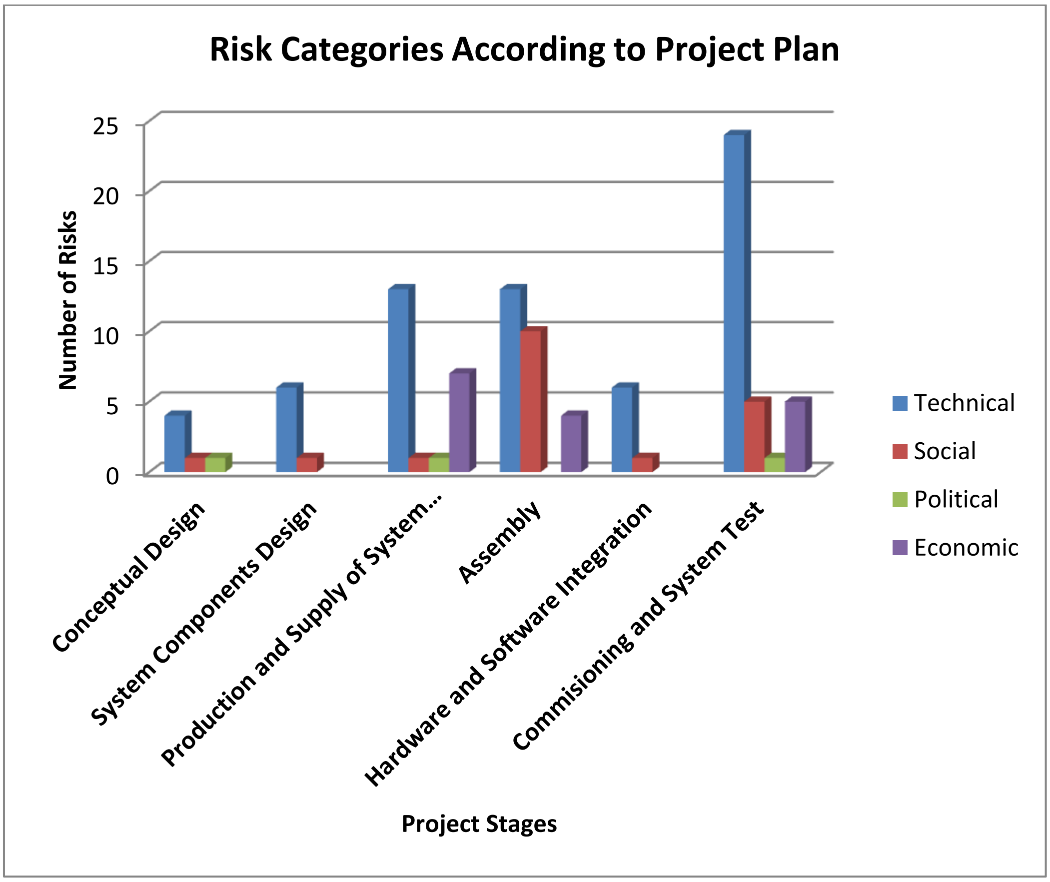


Figure 4.17 : Risk categories according to project plan.

Table 4.3 : Risk breakdown structure (2nd Level).

RBS Level 0	RBS Level 1	RBS Level 2
CSP Tower Project	1. Conceptual Design	1.1. Field settlement plan 1.2. Proces flow diagram 1.3. System modelling and simulation
	2. System Components Design	2.1. Heliostat design 2.2. Tower design 2.3. Receiver&Thermal equipments design 2.4. Software design
	3. Production and Supply of System Components	3.1. Heliostat components Production 3.2. Tower 3.3. Receiver and Thermal equipments
	4. Assembly	4.1. Heliostat erection 4.2. Tower erection 4.3. Receiver&Thermal equipments placement
	5. Hardware and Software Integration	5.1. Heliostat hardware and software integration 5.2. Receiver&Thermal proces hardware and software integration 5.3. Integration with central software
	6. Commisioning and System Tests	6.1. Concentration tests 6.2. Reflection tests 6.3. Temperature test 6.4. Pressure tests 6.5. Trial production 6.6. Thermal efficiency tests 6.7. Hot cycle efficiency analysis 6.8. Total system test

As it is mentioned above, risk distribution according to project plan and categories can be shown in the following figure (Figure 4.17), briefly. At all stages of project, technical risks are seen as the most risk.

In addition, risks are evaluated according to technical, social, political and economic categories.

In Technical Risks category (Figure 4.18) ; the numbers of identified risks are respectively as follows: conceptual design (4 risks), system components design (6 risks), production and supply of system components (13 risks), assembly (13 risks), hardware and software integration (6 risks), commisioning and system test (24 risks).

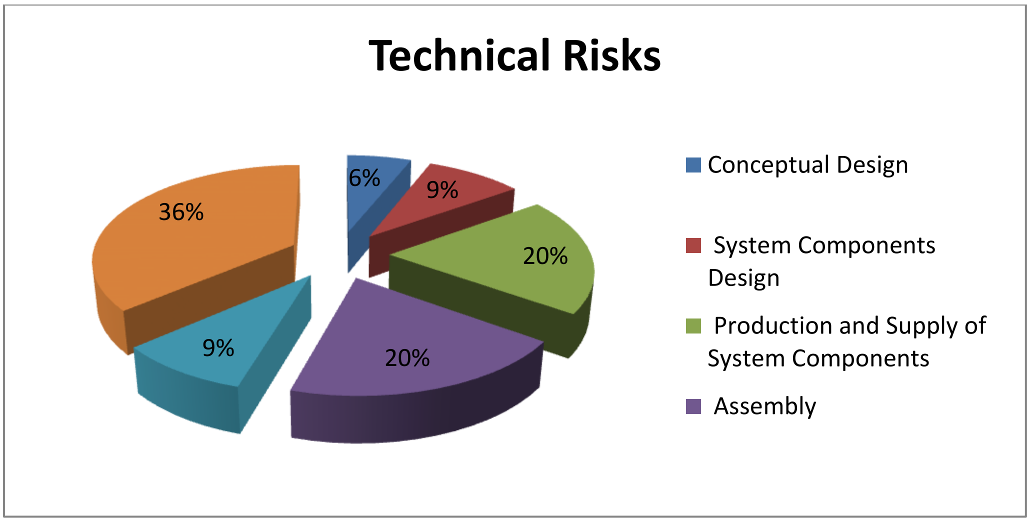


Figure 4.18 : Distribution of technical risks.

In Socail Risks category (Figure 4.19); the numbers of identified risks are respectively as follows: conceptual design (1 risk), system components design (1 risk), production and supply of system components (1 risk), assembly (10 risks), hardware and software integration (1 risk), commisioning and system test (5 risks).

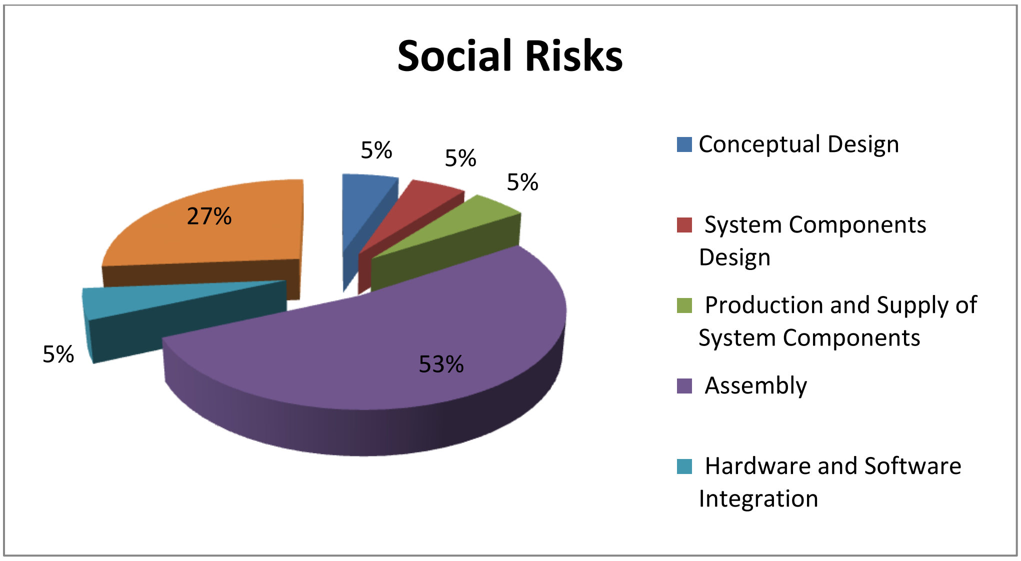


Figure 4.19 : Distribution of social risks.

In Political Risks category (Figure 4.20); the numbers of identified risks are respectively as follows: conceptual design (1 risk), production and supply of system components (1 risk), commisioning and system test (1 risk).

In system components design, assembly and hardware and software integration stages, political risks are not found.

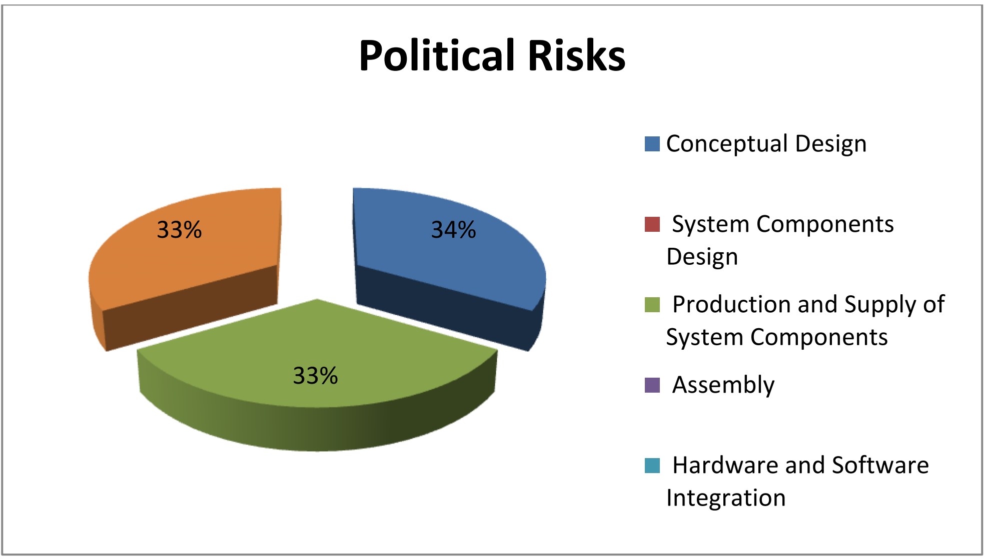


Figure 4.20 : Distribution of political risks.

When identified risks are evaluated according to economic category (Figure 4.21); the numbers of identified risks are respectively as follows: production and supply of system components risks (7), assembly (4), commisioning and system test (5). In conceptual design, system components design and hardware and software integration, political risks are not found.

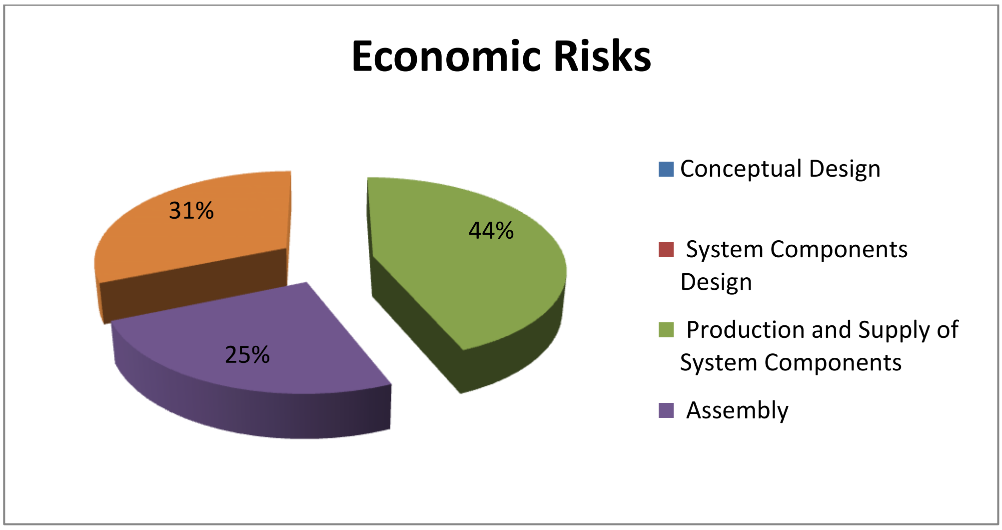


Figure 4.21 : Distribution of economic risks.

Accordingly, identified risks are evaluated by categories and by project phase. In this section, a summary of the risks according to their classification has been made with graphics and explanations. In the following section qualitative risk analysis has performed for identified technical risks.

4.3 Risk Analysis of ST1 Project

Qualitative analyzes were carried out within the scope of this thesis. In the following part (4.3.1), qualitative risk analysis has performed for “Technical” risk category of ST1 CSP Tower Project (given in App. E).

4.3.1 Qualitative risk analysis

For this project, qualitative risk analysis has performed for technical risks under the following headings of the project management stage:

- Conceptual design
- System components design
- Production and supply of system components
- Assembly
- Hardware and software integration
- Commisioning and system test

The impact and probability values of risks has emerged (given in App. F). According to these values risk levels of risks and risk matrix are prepared.

4.3.1.1 Risk analysis in conceptual design

When risk analysis has performed for the conceptual design stage, totally six (6) risks are identified. Sixty seven percent (67%) of the risks are technical, seventeen percent of risks (17%) are political and sixteen percent (16%) of risks are social risks.

Technical risk category includes the maximum number of risks in conceptual design stage of the project. Also percetages can be seen in Figure 4.22.

In Table 4.4, it is shown that impact and probability as numerical values. According to these values, risk levels are also calculated. As it can be understood from the table, in conceptual design phase includes low and medium levels of risk. In the conceptual design stage, despite the high efficacy of the risks, there is no risk level more than twelve which is medium risk level due to their low probability.

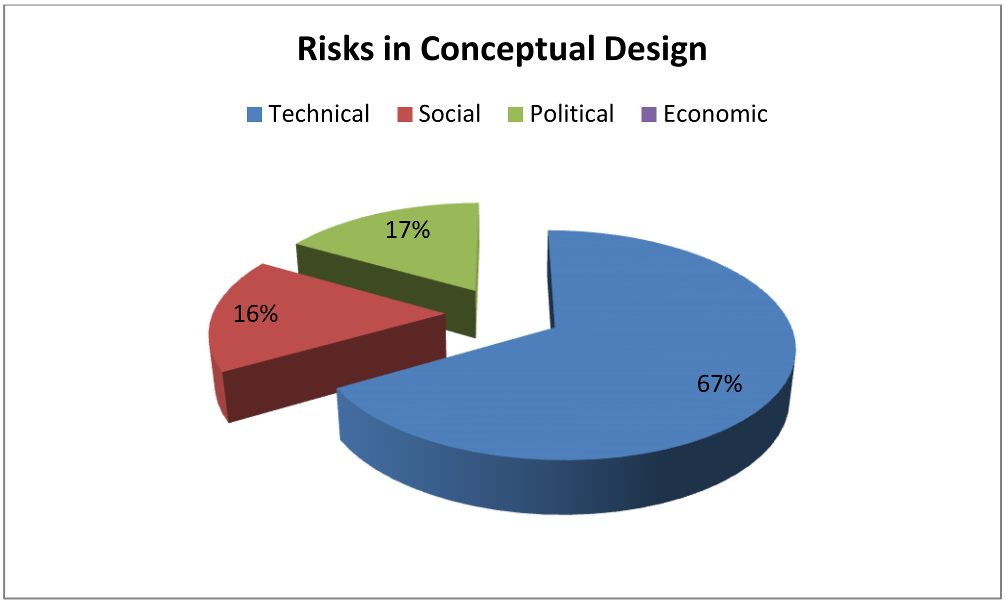


Figure 4.22 : Risk distribution of conceptual design stage.

This could be seen from the probability and impact matrix of the conceptual design risks (Figure 4.23).

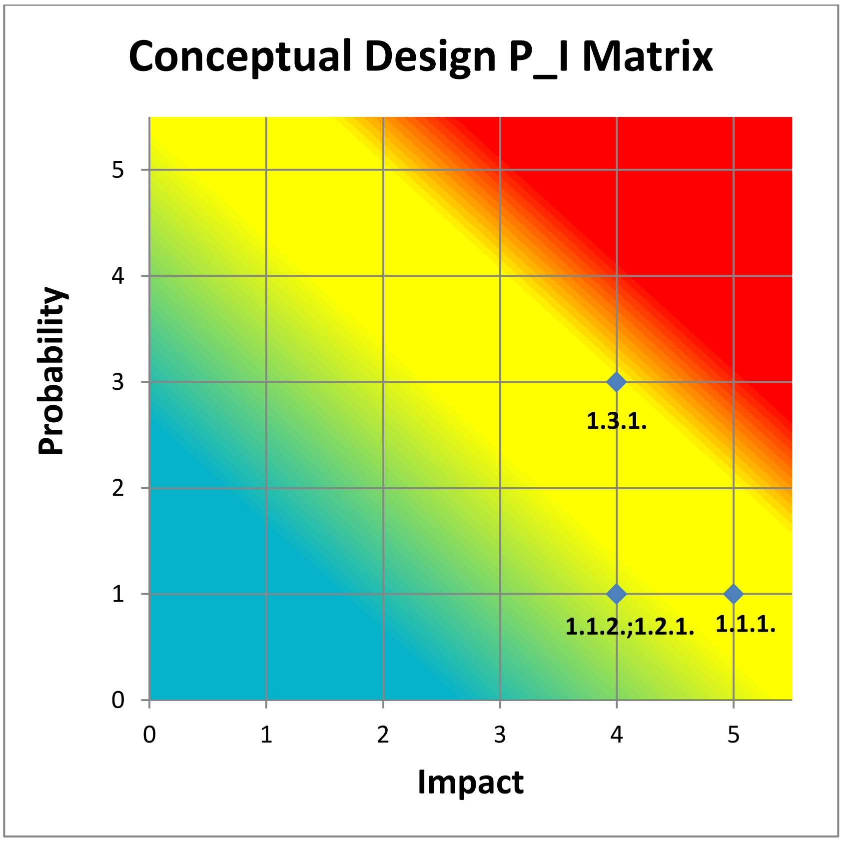


Figure 4.23 : Probability and impact matrix of conceptual design risks.

Table 4.4 : Technical risks of conceptual design.

Risk number in RBS	Risks	Impact	Probability	Numerical Risk Level	Risk Level
1.1.1.	Miscalculation in field settlement	5	1	5	Low
1.1.2.	Shadow effect	4	1	4	Low
1.2.1.	Incorrect drawing in proces flow diagram	4	1	4	Low
1.3.1.	Error in modelling and simulation programmes	4	3	12	Medium

The severity of the risks in conceptual design stage could be seen from the figure of risk levels (Figure 4.24) .

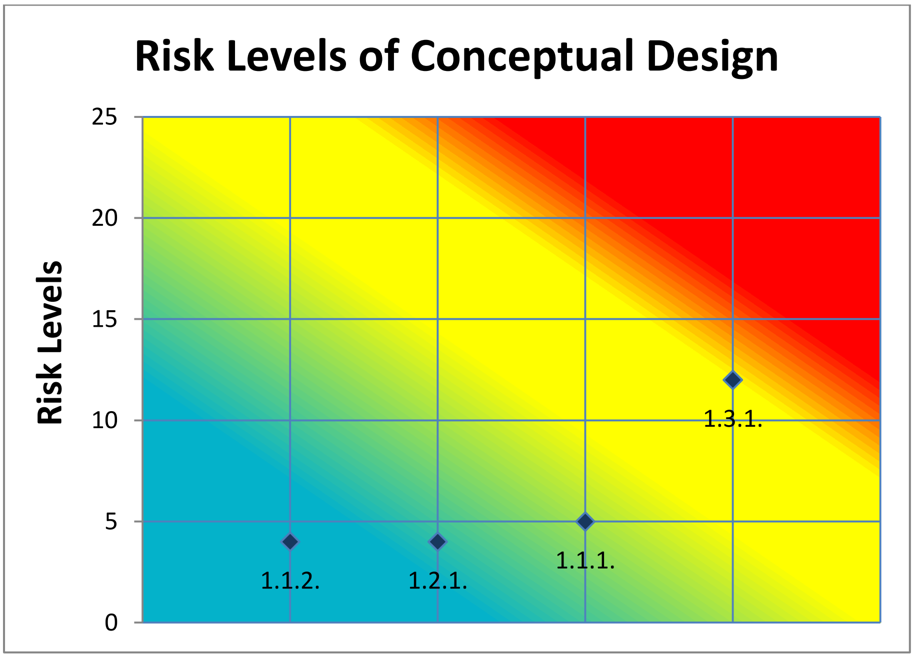


Figure 4.24 : Risk levels of conceptual design stage.

As a result, conceptual design phase does not include high risks. Because this is the first step of the project and the risks in the beginning can be easily determined and taken precautions for these risks.

4.3.1.2 Risk analysis in system components design

The second phase of the project is system component design. It is important that the design of the system components have to be designed correctly because the correct design affects the energy system efficiency directly. This phase includes (Figure 4.25) only technical (6 risks) and social risks (1 risk).

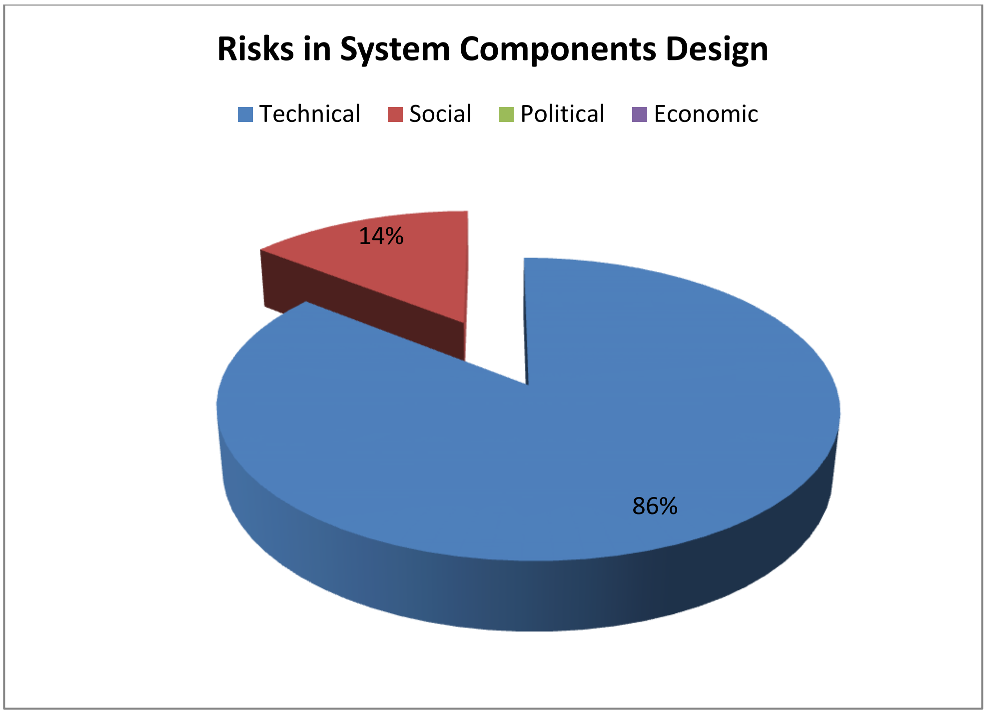


Figure 4.25 : Risk distribution of system components design stage.

When technical risks are considered in this phase according to their numercal values of impact and probability, the risk levels can be observed in low and medium levels, as a numerical value between 5 and 12 (shown in Table 4.5).

Table 4.5 : Technical risks of system components design.

Risk number in RBS	**Risks**	**Impact**	**Probability**	**Numerical Risk Level**	**Risk Level**
2.1.1.	Faulty Heliostat design	5	1	5	Low
2.2.1.	Wrong tower design	5	1	5	Low
2.3.1.	Design error in Receiver&Thermal equipments	5	1	5	Low
2.4.1.	Design error in software	5	2	10	Medium
2.1.2.	Unproper heliostat concrete reinforcement	4	3	12	Medium
2.1.3.	Revision need for wrong designed components	3	3	9	Medium

In the figure 4.26, the probability and impact values of the risks at this stage can be seen comparetively.

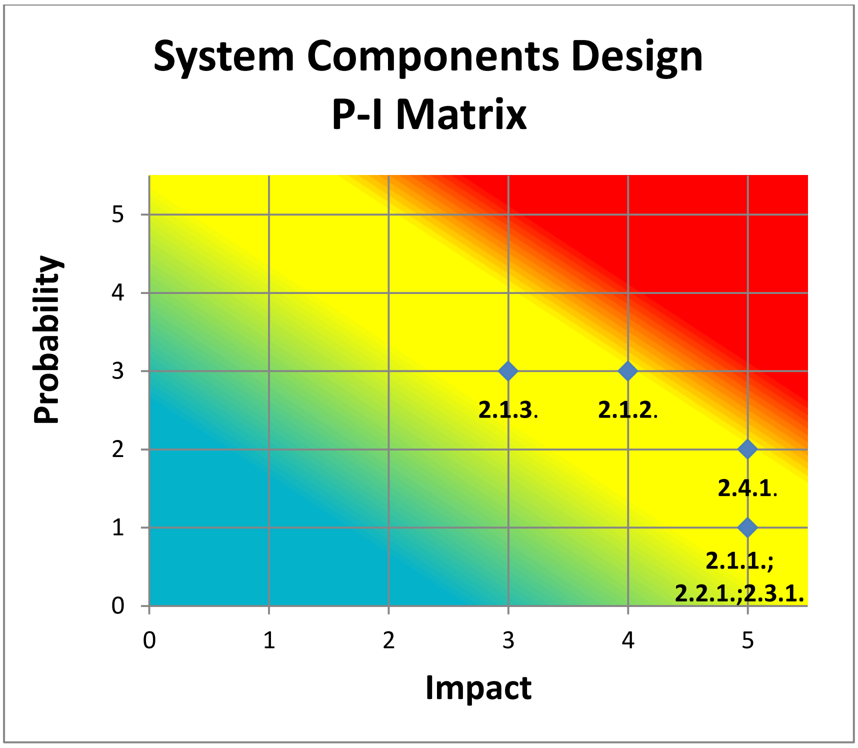


Figure 4.26 : Probability and impact matrix of system components design risks.

The risk levels of system components design stage are between 5 and 12 as numerical value as shown in Figure 4.27.

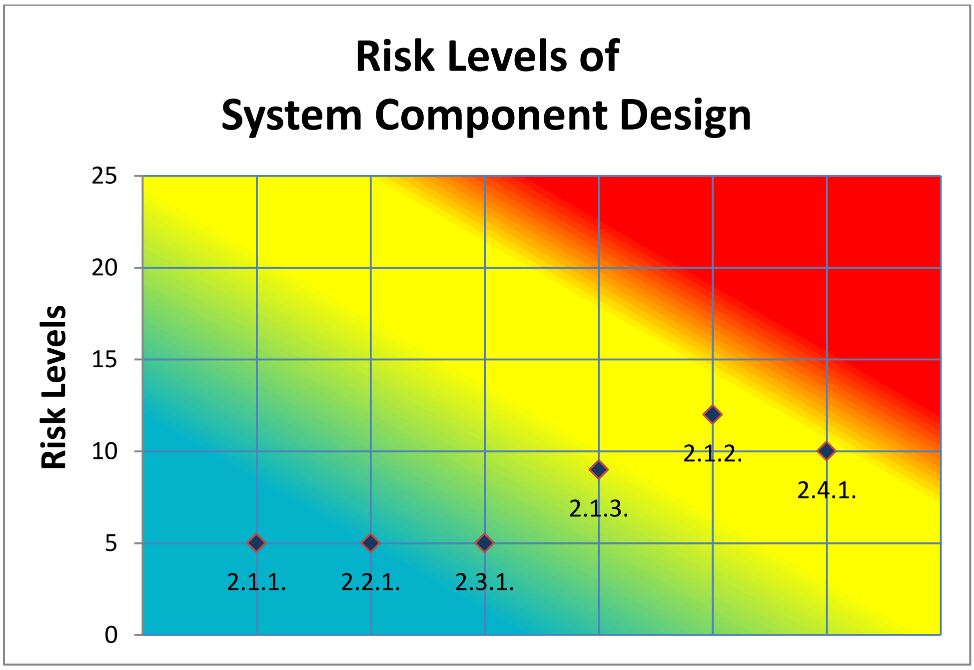


Figure 4.27 : Risk levels of system components design stage.

In conclusion, system component design stage, one of the most important step for the project, contains six technical risks with low and medium risk level.

4.3.1.3 Risk analysis in production and supply of system components

After system component design, “production and supply of system components” stage follows. This phase is also one of the important part affecting the success of the project. Also it involves more risks from the previous stages. Total number of the risk is twenty-two (22) which includes thirteeen technical, one social, one political, seven economic risks (Figure 4.28).

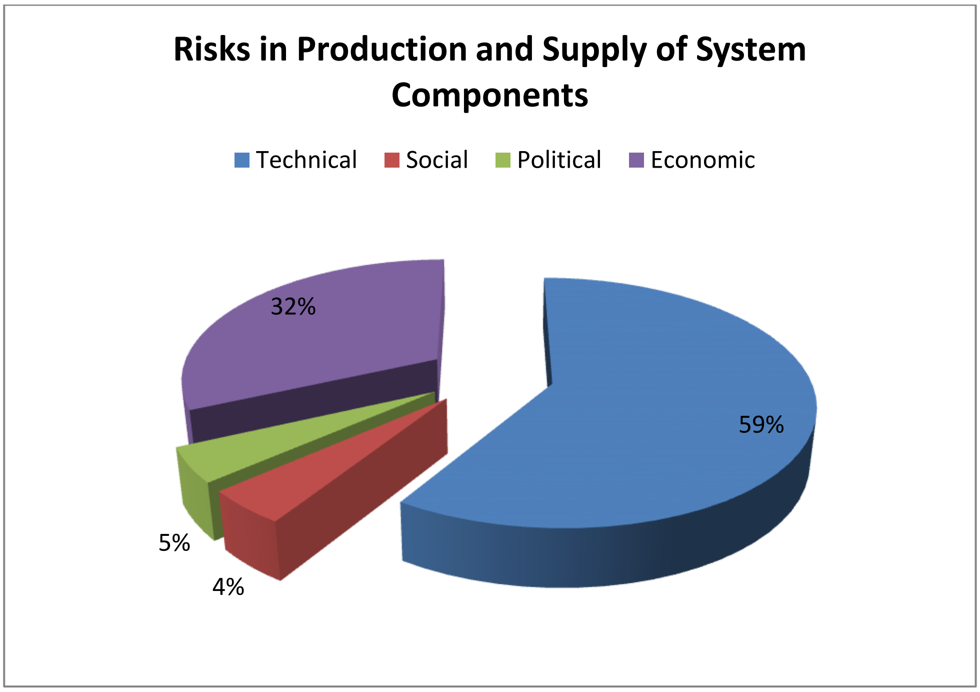


Figure 4.28 : Risk distribution of production and supply of system components stage.

As it is seen in the technical risk table (Table 4.6), most of risks (8 risks) are medium level, three of them are low level and one is high risk level. In this stage, by assessing the level of risks, project steps to be condisered can be identified. For example, in this phase insufficient quality control of the system components can cause high risk so this step must be done carefully.

Table 4.6 : Technical risks of production and supply of system components.

Risk number in RBS	Risks	Impact	Probability	Numerical Risk Level	Risk Level
3.1.2.	Backlash in gearbox	4	1	4	Low
3.1.3.	Error while producing interface in desired precision	4	1	4	Low
3.1.4.	Error while producing torque tube in desired precision	4	2	8	Medium
3.1.5.	Problem in the press when producing composite arms	4	2	8	Medium
3.1.6.	Production error in the desired reflection ratio of mirrors	4	2	8	Medium
3.1.7.	Failure in production of control box	4	3	12	Medium
3.2.1.	Oscillation in the tower	4	2	8	Medium
3.3.1.	Improper installation of pumps	5	2	10	Medium
3.3.2.	Improper installation of valves	5	2	10	Medium
3.1.7.	Failure in water treatment unit	4	2	8	Medium
3.3.10.	Failures in production patterns	3	2	6	Low
3.3.11.	Inadequate quality control	5	3	15	High

According to probability and impact matrix of production and supply of system components stage (Figure 4.29), the maximum value for the probability is 3 and for impact is five for this stage.

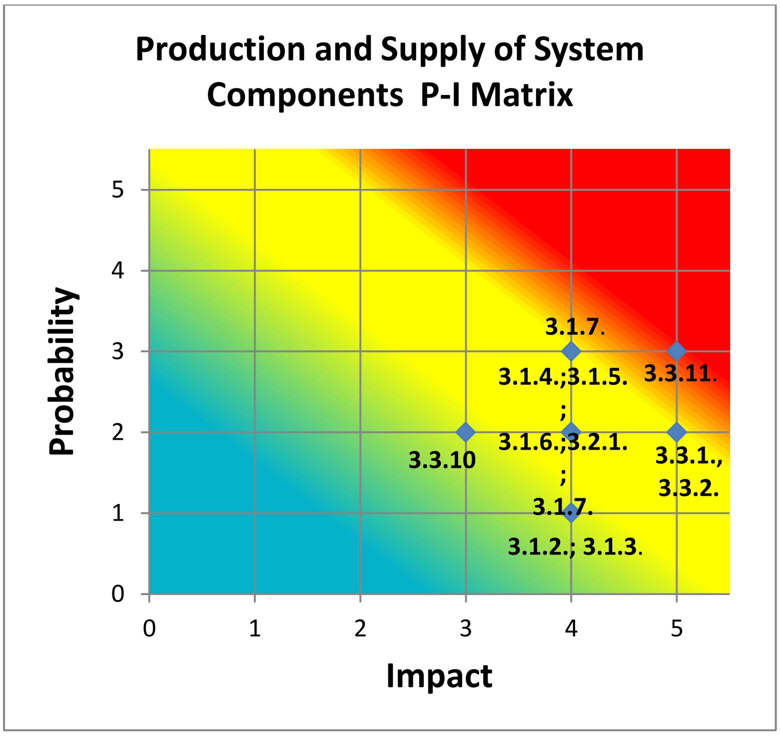


Figure 4.29 : Probability and impact matrix of production and supply of system components risks.

When considering the level of risk (Figure 4.30), the values vary from the range of four (4) and fifteen (15). The value of most of risk levels are eight (8).

Consequently, production and supply of system components stage is risky stage for the projects. Many risks in this stage have the greatest impact but their probabilities are not more than three (3). Thus these risks have controllable (low and medium) risk levels.

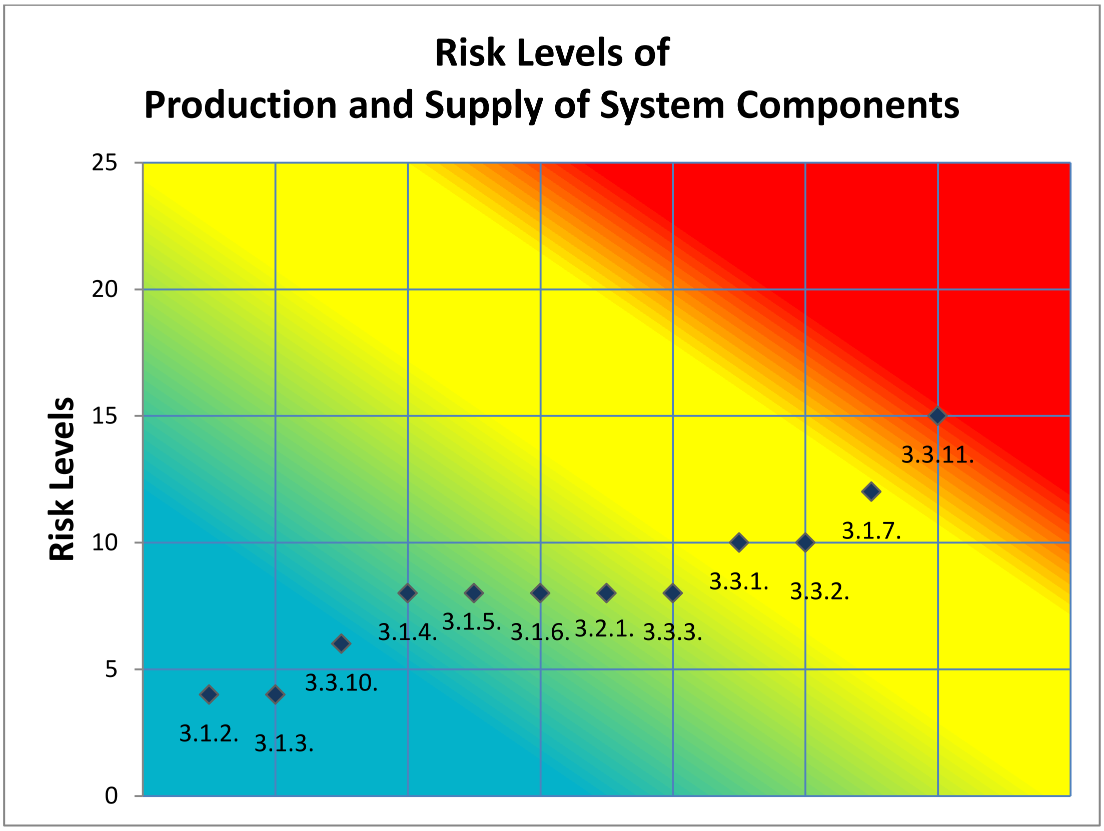


Figure 4.30 : Risk levels of production and supply of system components stage.

4.3.1.4 Risk analysis in assembly

When risk analysis has performed for assembly stage, totally twenty-seven (27) risks are identified. Forty-eight percent (48%) of the risks are technical, thirty-seven percent of risks (37%) are social risks and fifteen percent (15%) of the risks are economic risks (Figure 4.31). Technical risk category includes the maximum number of risks in assembly stage of the project.

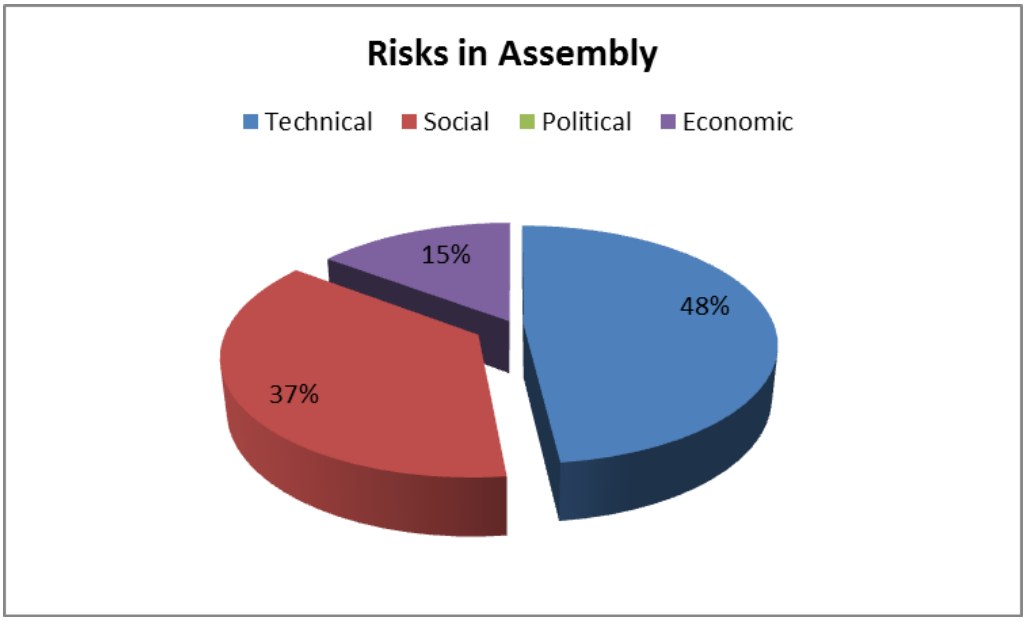


Figure 4.31 : Risk distribution of assembly stage.

Installation of system components is also important stage as the design stage in the project. At this stage, risks have high effects. The risks in this phase are more critical because of their medium and high risk levels (shown in Table 4.7).

Table 4.7 : Technical risks of assembly.

Risk number in RBS	**Risks**	**Impact**	**Probability**	**Numerical Risk Level**	**Risk Level**
4.3.1.	Improper boiler installation	5	2	10	Medium
4.3.2.	Improper piping installation	5	2	10	Medium
4.3.3.	Insufficient insulation	5	2	10	Medium
4.3.4.	Improper fittings installation	5	2	10	Medium
4.3.20.	Incorrect placement of the condenser	3	2	6	Low
4.1.1.	Improper heliostat erection	5	3	15	High
4.2.1.	High tower construction problem	5	3	15	High
4.3.8.	Bad weather condition during construction	4	3	12	Medium
4.3.9.	Deterioration of the heliostat carrier crane in the assembly area	3	3	9	Medium
4.3.11.	Failure of assembly instruments	4	2	8	Medium
4.3.11.	Material loss during installation	3	3	9	Medium
4.2.16.	Wrong welding in tower construction	4	2	8	Medium

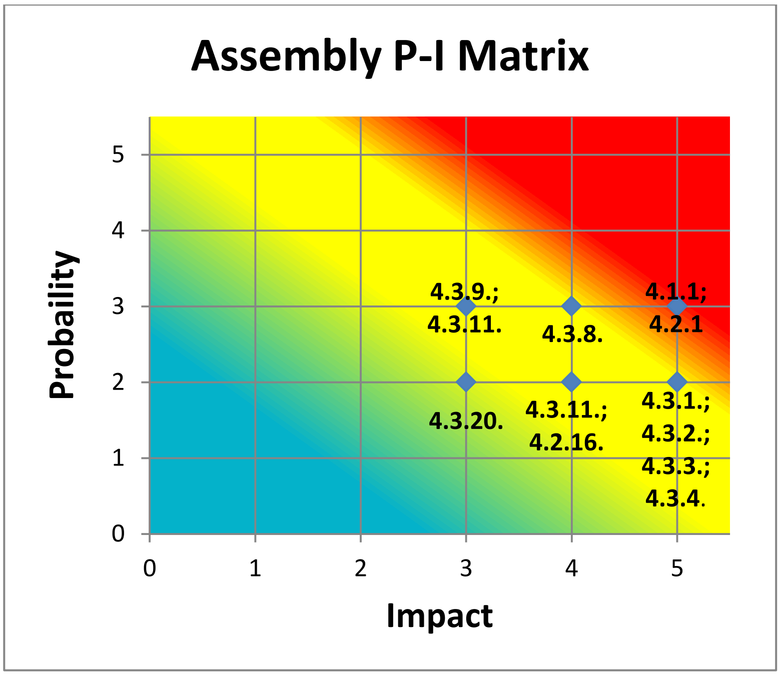


Figure 4.32 : Probability and impact matrix of assembly risks.

In the Figure 4.32, the probability and impact values of the risks at this stage can be seen comparetively.

In the assembly stage, the majority is medium level risks. The issues related with heliostat and tower erection have greatest risk with fifteen (15) risk level value (Figure 4.33).

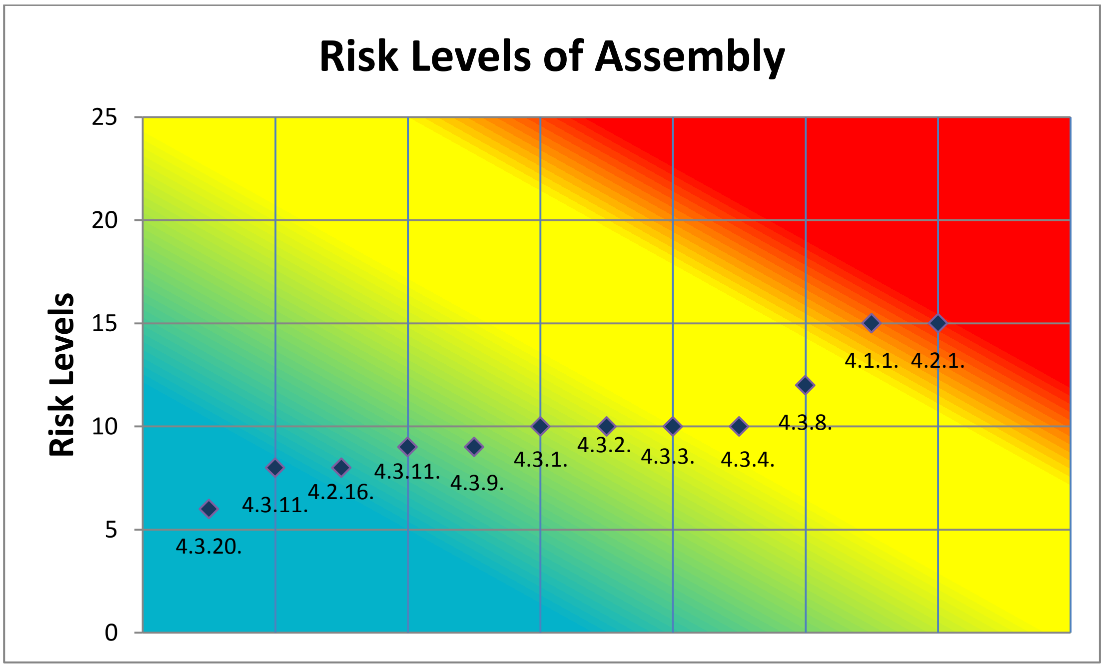


Figure 4.33 : Risk levels of assembly stage.

Accordingly, assembly stage includes important risks related to components installation. The levels of risks are between 6 and 15, most of them have medium risk level.

4.3.1.5 Risk analysis in hardware and software integration

The fifth phase of the project is hardware and software integration. This phase includes only technical (6 risks) and social risks (1 risk) (Figure 4.34).

When technical risks are considered in this phase according to their numercal values of impact and probability, the risk levels can be observed in high and medium levels, as a numerical value between 10 to 25 (Table 4.8).

Hardware and Software Integration stage is one of the most risky part of the project due to its technical risks. The impact of the identified risks is maximum value: five (5) for all risks. The probability of risks are also high (Figure 4.35).

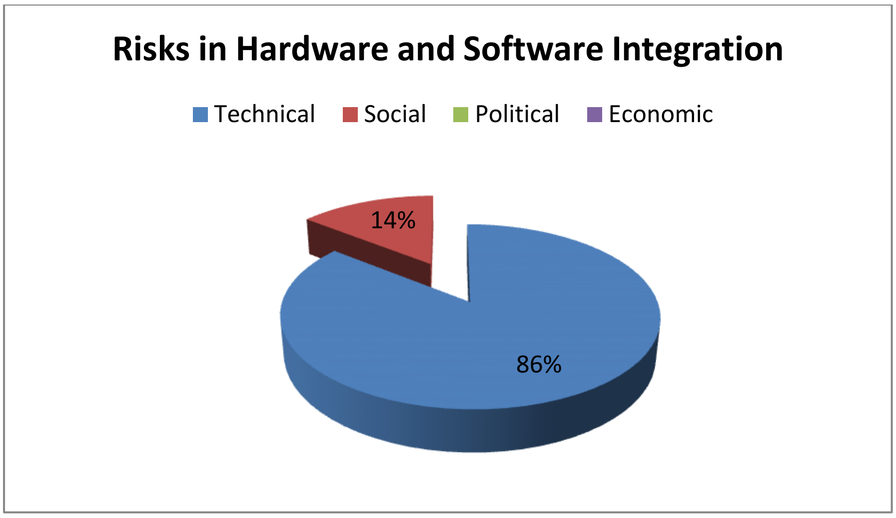


Figure 4.34 : Risk distribution of hardware and software integration stage.

Table 4.8 : Technical risks of hardware and software integration.

Risk number in RBS	Risks	Impact	Probability	Numerical Risk Level	Risk Level
5.1.1.	Wireless communication problems of heliostats	5	5	25	High
5.1.2.	Connection problems with main software	5	2	10	Medium
5.1.3.	Communication problems of receiver and heliostats	5	4	20	High
5.2.1.	Problem of receiver otomation	5	2	10	Medium

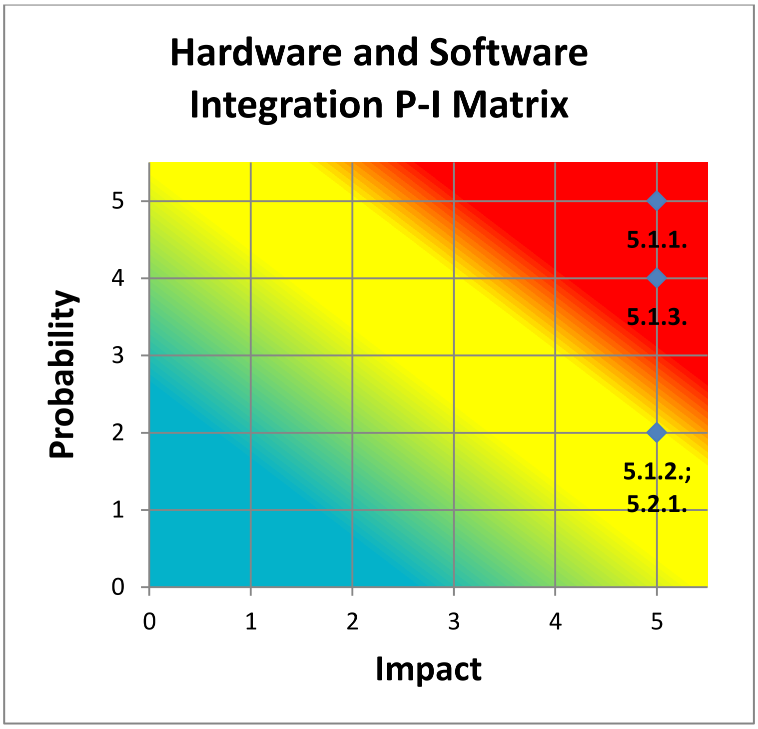


Figure 4.35 : Probability and impact matrix of hardware and software integration risks.

These higher probability and impact values result high risk level. As it is seen in the Figure 4.36, two of risks have high risk levels, one has medium and one has low risk level.

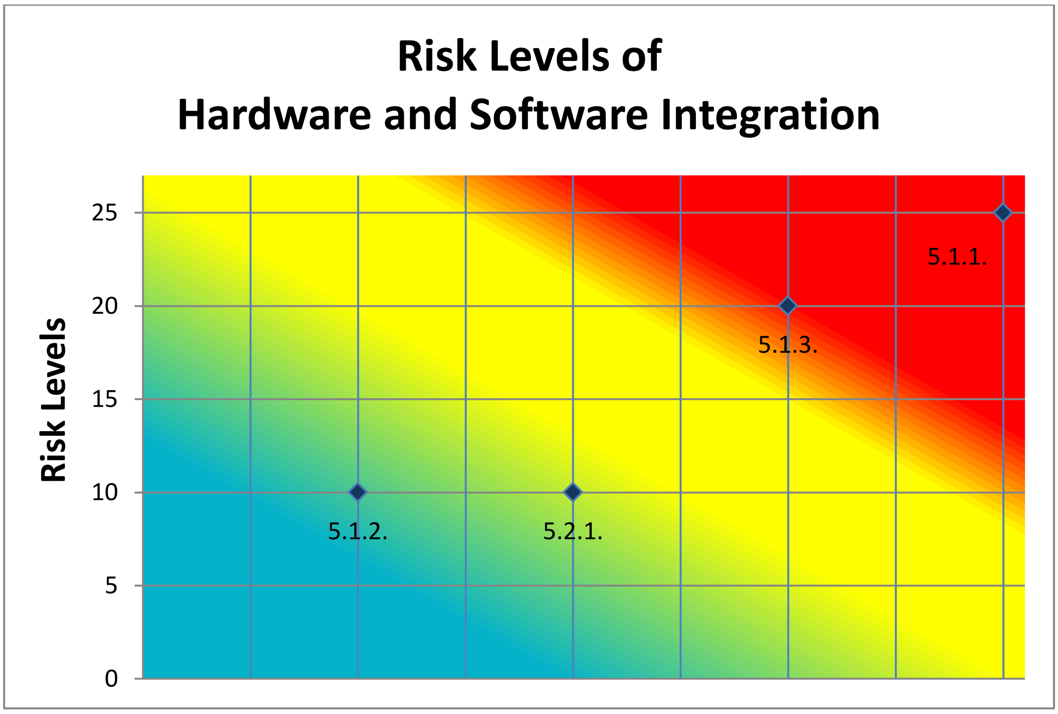


Figure 4.36 : Risk levels of hardware and software integration stage.

As a result, because of communication and connection between hardware and software of the system, this stage has more high level risks.

4.3.1.6 Risk analysis in commissioning and system test

After hardware and software integration stage, “commissioning and system test” stage follows. This is the stage that contains the highest number of risk..

Additionally, this phase is the last step of the project, involving mostly medium risks. Total number of the risk is thirty-five (35) which includes twenty-four (24) technical, five (5) social, one (1) political and five (5) economic risks (Figure 4.37).

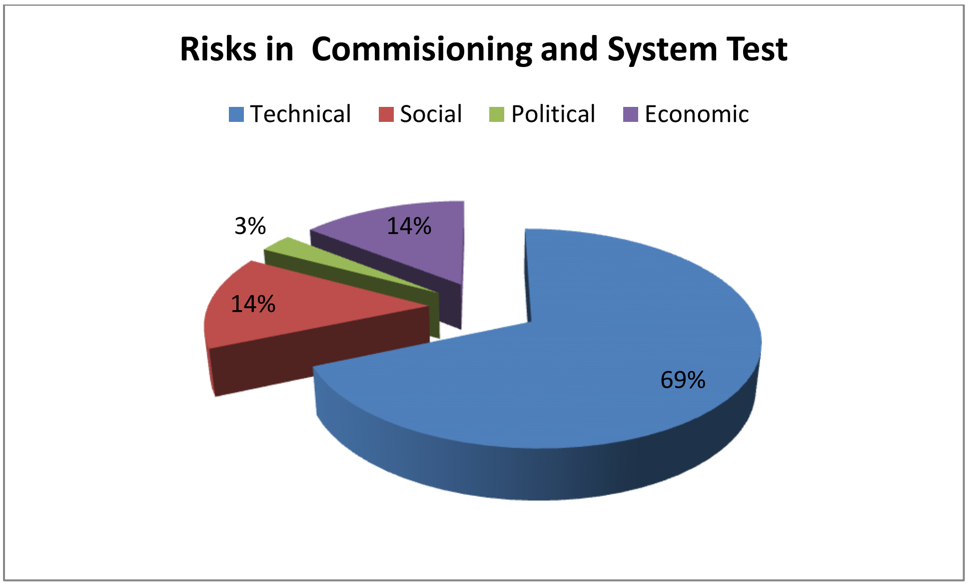


Figure 4.37 : Risk distirbution of commisioning and system test stage.

In Table 4.9, it is shown that impact and probability of risks as numerical values. According to these values, risk levels are also calculated and evaluated whether it is high, medium or low risk.

According to this analysis, technical risks of commisioning and system test stage includes 4 high, 17 medium and 3 low risks. Most of the medium risks has 10 risk level value as shown in Figure 4.38. The most critical risk is “problem in signaling in abnormal cases” in this stage.

Table 4.9 : Technical risks of commisioning and system test.

Risk number in RBS	Risks	Impact	Probability	Numerical Risk Level	Risk Level
6.1.1.	Deformation of receiver due to high temperature	5	2	10	Medium
6.1.2.	Deformation of receiver due to high pressure	5	2	10	Medium
6.8.1.	Insufficient gas purification in deaerator unit	3	2	6	Low
6.5.1.	Too low or too high inlet steam flow rate	5	2	10	Medium
6.3.2.	Too low or too high inlet steam temperature	5	2	10	Medium
6.4.2.	Too low or too high inlet steam pressure	5	2	10	Medium
6.5.2.	Too low or too high exhaust vapor flow rate	5	2	10	Medium
6.3.3.	Too low or too high exhaust vapor temperature	5	2	10	Medium
6.4.3.	Too low or too high exhaust vapor pressure	5	2	10	Medium
6.1.3.	Heliostat concentration problem	3	3	9	Medium
6.1.4.	Mirror reflection failure	4	1	4	Low
6.6.1.	Excessive heating in thermal system components	5	2	10	Medium
6.3.4.	Temperature sensor problem	5	2	10	Medium
6.4.4.	Pressure sensor problem	5	2	10	Medium
6.5.3.	Flow rate measurement equipment problem	5	2	10	Medium
6.3.5.	Increasing cooling water temperature	5	2	10	Medium
6.8.8.	Lower yield	5	2	10	Medium
6.8.9.	Difficult acces to site (like desert area)	4	4	16	High
6.8.10.	Failure of measuring instruments	4	3	12	Medium
6.8.11.	Problem in signaling in abnormal cases	5	5	25	High
6.8.12.	Corruption of the calibration device	5	1	5	Low
6.1.5.	Excessive dust on reflective mirror	4	5	20	High
6.7.1.	Erosion of the surface paint of thermal components	4	4	16	High
6.8.16.	Missing grounding in electrical equipment	4	2	8	Medium

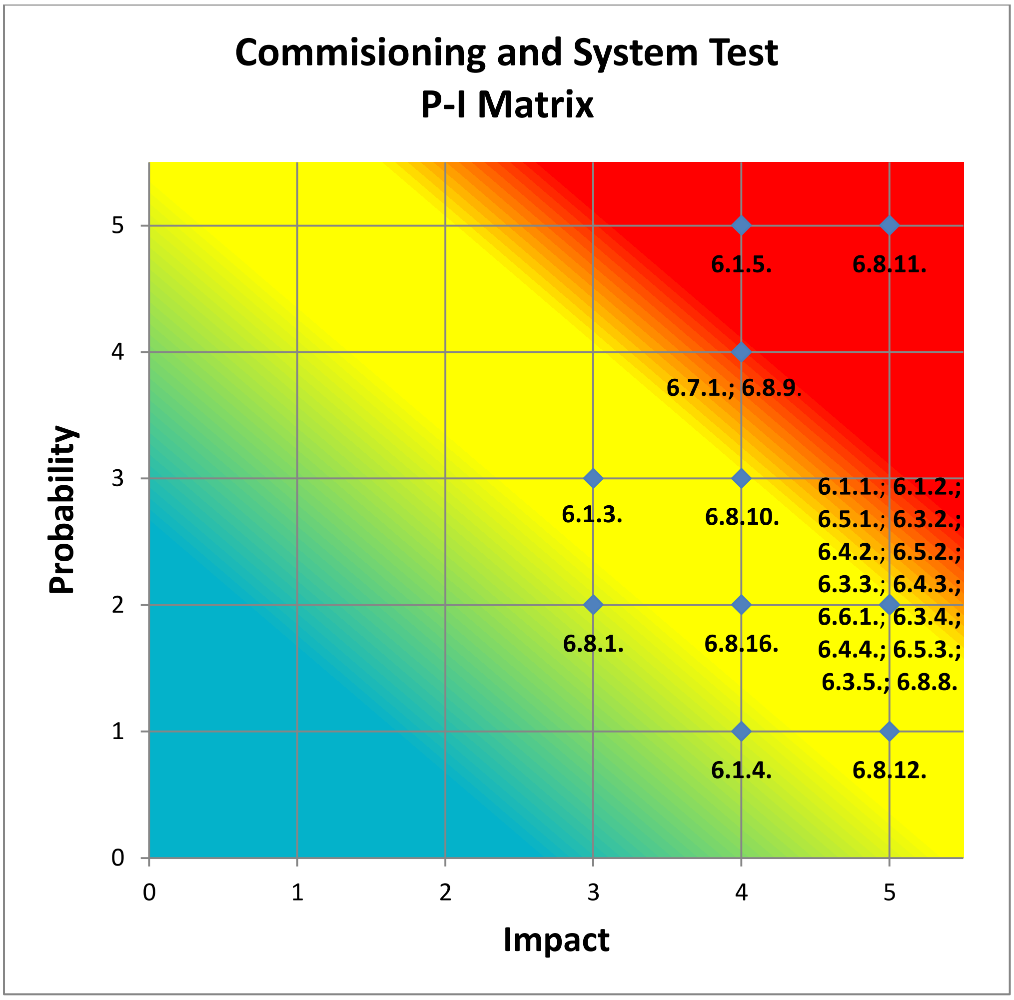


Figure 4.38 : Probability and impact matrix of commisioning and system tests risks.

As it can be understood from the Figure 4.39, in commisioning and system test phase includes mostly high and medium levels of risk.

When technical risks are considered in this phase according to their numerical values, risk levels can be observed in low, medium and high levels, starting from 4 and goes to 25 value.

In conclusion; commisioning and system tests, the last and risky stage of the project, contains totally 24 technical risks. Many risks in this stage have the greatest impact. The levels of risks changes between 4 and 25, most of them have medium risk level.

In summary, technical risks of the project are evaluated according to their probability, impact and risk level. Each stage of the project is studied separately. The stage containing the most risk is the last stage, commisioning and system tests with 24 risks.

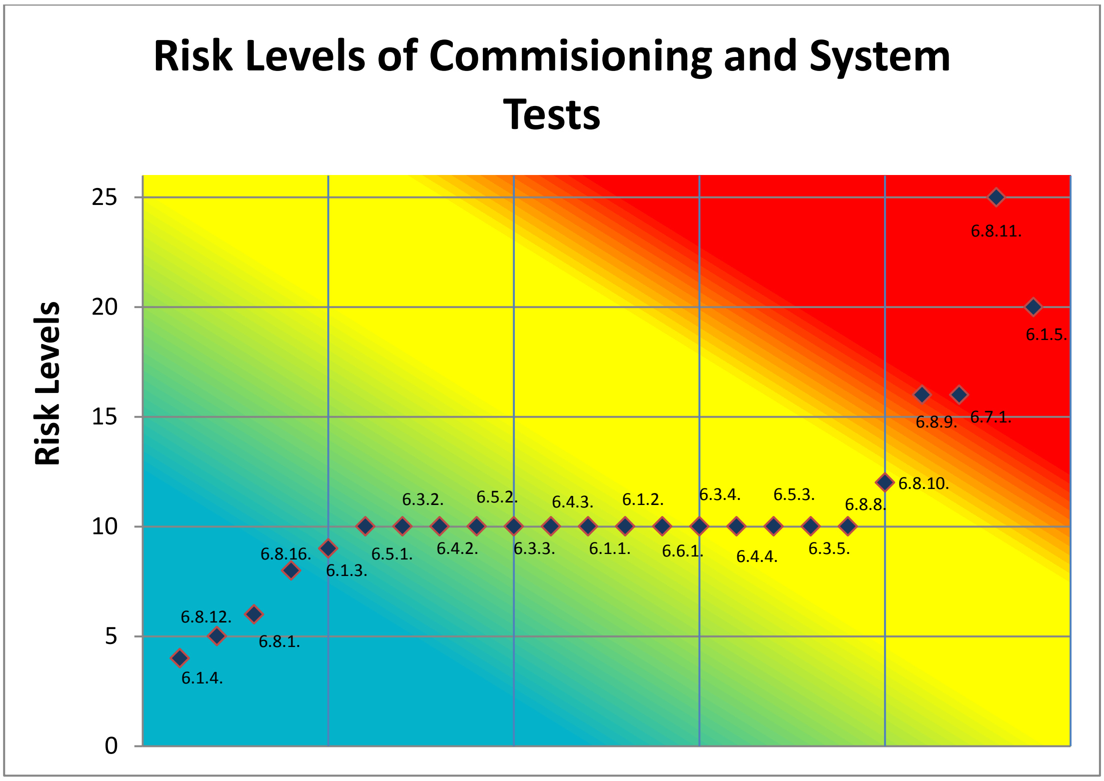


Figure 4.39 : Risk levels of commisioning and system tests stage.

4.3.2 Quantitative risk analysis

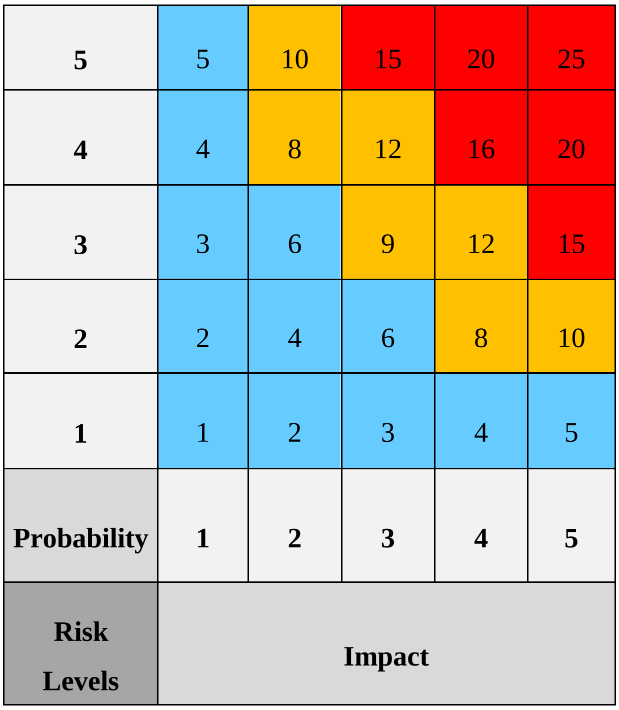
Precise information is required for quantitative risk analysis. In this study, because of the unprecise outputs of foreseeable risks, the effect of risk in terms of time and money (temporal and monetary) will not be calculated for all risks.

For example; if we look at the risk numbered 6.1.5. in the risk breakdown structure "Excessive dust on reflective mirror", in order to evaluate this risk based on the quantitative risk analysis, the answer of the following questions as numerically must be known: "how often they are getting dirty?", "how the dirtiness affect the reflection efficiency of the mirror?", "which method (water or dry washing) is used to clean the mirrors?", "how many people can clean the mirror?", "how much water is used to clean the mirror?", "what is the cleaning cost per mirror?". Even for only one risk; accurate and numerical information is needed for quantitative risk anlysis. Thus; quantitative risk analysis is outside the scope of this thesis.

4.4 Risk Response Planning and Risk Control for ST1 Project

Detailed risk response plan preparation and risk control are outside the scope of this thesis. However, risks could be prioritized according to identified risk level as shown in Figure 4.40. Risk response and control priority is as follows: high, medium and low risks. The first-priority risks are the high-risk levels, which have risk levels between fifteen (15) and twenty-five (25). The second priority risks are medium level risks, which have risk levels between eight (8) and twelve (12). The third priority risks are low risk levels, which have risk levels between one (1) and six (6) according to risk level matrix.

By using strategies such as risk avoidance and risk reduction, probability and impact of risks can be reduced. Until risk is brought up to acceptable limits; work can be stopped, controls can be increased, monitoring and measurement plan is made and records are kept an also as much as possible improvements must be followed, monitored and reported to management.



5	5	10	15	20	25
4	4	8	12	16	20
3	3	6	9	12	15
2	2	4	6	8	10
1	1	2	3	4	5
Probability	**1**	**2**	**3**	**4**	**5**
Risk Levels	**Impact**				

Figure 4.40 : Risk level priority.

5. CONCLUSION

Along with these study, it has been approved the applicability of risk management to renewable energy projects. The energy of the future is sustainable, renewable energy sources. Inorder to utilize these renewable energy sources in an efficient manner, potential risks must be identified and managed.

Risk management has a great importance in terms of both increasing quality and cost reduction. Risks must be managed firmly to achieve the objectives of the project.

In this thesis, the case of an exemplary CSP tower steam production plant project called ST1 is studied. After preparation of project plan (App. A) and time table (App.B), risk analysis is decided to be according to the project stages.

Project risk analysis has been evaluated for this case. Consequently, the risks are identified as follows (App. C): conceptual design stage: six (6) risks, system components design stage: seven (7) risks, production and supply of system components: twenty-two (22) risks, assembly: twenty- seven (27) risk, hardware and software integration: seven (7) risks, commisioning and system test: thirty-five (35) risks. Additionally; these identified risks are evaluated as following categories. The number of technical, social, economic and political risks are sixty- two (62), thirteen (13), thirteen (13) and three (3) in this order.

After all of the project risks are identified, technical risks are analyzed qualitatively. According to this analysis; the number of technical risks are in each project stage as follows (App. E): in conceptual design stage: four (4); in system components design stage: six (6); in production and supply of system components stage: thirteen (13); in assembly stage: (13); in hardware and software integration stage: six (6); in commisioning and system test stage:twenty-four (24).

Also technical risks are analyzed in terms of probability and impact values (App. F). The first-priority risks are the high-risk levels (risk level value between 15 and 25). The second priority risks are medium level risks (risk level value between 8 and 12).

The third priority risks are low risk levels (risk level value between 1and 6) according to risk level matrix.

According to qualitative risk analysis, technical risks have fourteen (14) low level risks, thirty-nine (39) medium level risks and nine (9) high level risks. As it is seen from the results, most of risks are medium level risks. The stage containing the most risk is the last stage, commisioning and system tests with twenty-four (24) risks.

After this study, future work suggestions are as follows:

- Identified uncertainities must be evaluated as risks and they have to be managed,
- The project management plans associated with risks need to be updated,
- Project plan and time table should be reevaluated considering the identified risks,
- If accurate information (temporal and monetary) exists, quantitative risk analysis can be performed,
- Probabilities and impacts of risks can be reevaluated,
- Until risk is brought up to acceptable limits; work can be stopped, controls can be increased, monitoring and measurement plan is made and records are kept an also as much as possible improvements must be followed, monitored and reported to management,
- Risk management cycle should be continued.

This is the overview of this master thesis. Risk analysis is not limited to this study. with more numerical risk data, more comprehensive study can be done for future study.

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APPENDICES

APPENDIX A

Table A.1: Project plan.

1. Conceptual Design	**2. System Components Design**	**3. Production and Supply of System Components**	**4. Assembly**	**5. Hardware and Software Integration**	**6. Commisioning and System Tests**
1.1. Field settlement plan	2.1. Heliostat design	3.1. Heliostat components Production	4.1. Heliostat erection	5.1. Heliostat hardware and software integration	6.1. Concentration tests
1.2. Proces flow diagram	2.2. Tower design	3.1.1. Heliostat Concrete Reinforcement	4.2. Tower erection	5.2. Receiver&Thermal proces hardware and software integration	6.2. Reflection tests
1.3. System modelling and simulation	2.3. Receiver& Thermal equipments design	3.1.2. Heliostat Anchor	4.3. Receiver& Thermal equipments placement	5.3. Integration with central software	6.3. Temperature test
	2.4. Software design	3.1.3. Gearbox System			6.4. Pressure tests
		3.1.4. Interface			6.5. Trial production
		3.1.5. Torque tube			6.6. Thermal efficiency tests
		3.1.6. Composite support			6.7. Hot cycle efficiency analysis
		3.1.7. Linear actuator			6.8. Total system test
		3.1.8. Reflective mirror			
		3.1.9. Control box			
		3.2. Tower			
		3.3. Receiver and Thermal equipments			
		3.3.1. Receiver			
		3.3.2. Boiler			
		3.3.3. Pumps			
		3.3.4. Piping			
		3.3.5. Water treatment unit			
		3.3.6. Insulation			
		3.3.7. Fittings			
		3.3.8. Condenser			
		3.3.9. Deaerator			

APPENDIX B

Table B.1: Project time table.

	PROJE ADI : ST1 CSP Tower Project	DURATION	1st year						2nd year					
			Month 1 and 2	Month 3 and 4	Month 5 and 6	Month 7 and 8	Month 9 and 10	Month 11 and 12	Month 1 and 2	Month 3 and 4	Month 5 and 6	Month 7 and 8	Month 9 and 10	Month 11 and 12
NO	Project Time Table													
1	CONCEPTUAL DESIGN	2 MONTH	x x x x											
1.1	Field Settlement Plan		- - - -											
1.2	Process Flow Diagram		- - - -											
1.3	System Modelling and Simulation		- - - -											
2	SYSTEM COMPONENTS DESIGN	4 MONTHS	x x	x x x x	x x									
2.1	Heliostat Design		- -	- - - -	- -									
2.2	Tower Design		- -	- - - -	- -									
2.3	Receiver&Thermal Equipments Design		- -	- - - -	- -									
2.4	Software Design		- -	- - - -	- -									
3	PRODUCTION AND SUPPLY OF SYSTEM COMPONENTS	10 MONTHS		x x	x x x x	x x x x	x x x x	x x x x	x x					
3.1	Heliostat components Production			- -	- - - -	- - - -	- - - -	- - - -	- -					
3.1.1	Heliostat Concrete Reinforcement			- -	- - - -	- - - -	- - - -	- - - -	- -					
3.1.2	Heliostat Anchor			- -	- - - -	- - - -	- - - -	- - - -	- -					
3.1.3	Gearbox System			- -	- - - -	- - - -	- - - -	- - - -	- -					
3.1.4	Interface			- -	- - - -	- - - -	- - - -	- - - -	- -					
3.1.5	Torque tube			- -	- - - -	- - - -	- - - -	- - - -	- -					
3.1.6	Composite support			- -	- - - -	- - - -	- - - -	- - - -	- -					
3.1.7	Linear actuator			- -	- - - -	- - - -	- - - -	- - - -	- -					
3.1.8	Reflective mirror			- -	- - - -	- - - -	- - - -	- - - -	- -					
3.1.9	Control box			- -	- - - -	- - - -	- - - -	- - - -	- -					
3.2	Tower			- -	- - - -	- - - -	- - - -	- - - -	- -					
3.3	Receiver and Thermal equipments			- -	- - - -	- - - -	- - - -	- - - -	- -					
3.3.1	Receiver			- -	- - - -	- - - -	- - - -	- - - -	- -					
3.3.2	Boiler			- -	- - - -	- - - -	- - - -	- - - -	- -					
3.3.3	Pumps			- -	- - - -	- - - -	- - - -	- - - -	- -					
3.3.4	Piping			- -	- - - -	- - - -	- - - -	- - - -	- -					
3.3.5	Water treatment unit			- -	- - - -	- - - -	- - - -	- - - -	- -					
3.3.6	Insulation			- -	- - - -	- - - -	- - - -	- - - -	- -					
3.3.7	Fittings			- -	- - - -	- - - -	- - - -	- - - -	- -					
3.3.8	Condenser			- -	- - - -	- - - -	- - - -	- - - -	- -					
3.3.9	Deaerator			- -	- - - -	- - - -	- - - -	- - - -	- -					
4	ASSEMBLY, HARDWARE AND SOFTWARE INTEGRATION	12 MONTHS			x x	x x x x	x x x x	x x x x	x x x x	x x x x	x x			
4.1	Heliostat erection				- -	- - - -	- - - -	- - - -	- - - -	- - - -	- -			
4.2	Tower erection				- -	- - - -	- - - -	- - - -	- - - -	- - - -	- -			
4.3	Receiver&Thermal equipments placement				- -	- - - -	- - - -	- - - -	- - - -	- - - -	- -			
4.4	Heliostat hardware and software integration				- -	- - - -	- - - -	- - - -	- - - -	- - - -	- -			
4.5	Receiver&Thermal proces hardware and software integration				- -	- - - -	- - - -	- - - -	- - - -	- - - -	- -			
4.6	Integration with central software				- -	- - - -	- - - -	- - - -	- - - -	- - - -	- -			
5	COMMISIONING AND SYSTEM TESTS	12 MONTHS							x x x x	x x x x	x x x x	x x x x	x x x x	x x x x
5.1	Concentration tests								- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
5.2	Reflection tests								- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
5.3	Temperature test								- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
5.4	Pressure tests								- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
5.5	Trial production								- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
5.6	Thermal efficiency tests								- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
5.7	Hot cycle efficiency analysis								- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
5.8	Total system test								- - - -	- - - -	- - - -	- - - -	- - - -	- - - -

APPENDIX C

Table C.1: Risk identification table.

			In which phase(s) does the risk cause concern?					
Number	**Category**	**Risk**	**Conceptual Design**	**System Components Design**	**Production and Supply of System Components**	**Assembly**	**Hardware and Software Integration**	**Commisioning and System Test**
1	Technical	Miscalculation in field settlement	**X**					
2	Technical	Shadow effect	**X**					
3	Technical	Incorrect drawing in proces flow diagram	**X**					
4	Technical	Error in modelling and simulation programmes	**X**					
5	Technical	Faulty Heliostat design		**X**				
6	Technical	Wrong tower design		**X**				
7	Technical	Design error in Receiver&Thermal equipments		**X**				
8	Technical	Design error in software		**X**				
9	Technical	Unproper heliostat concrete reinforcement		**X**	**X**			
10	Technical	Backlash in gearbox			**X**			
11	Technical	Error while producing interface in desired precision			**X**			
12	Technical	Error while producing torque tube in desired precision			**X**			
13	Technical	Problem in the press when producing composite arms			**X**			
14	Technical	Production error in the desired reflection ratio of mirrors			**X**			
15	Technical	Failure in production of control box			**X**			
16	Technical	Oscillation in the tower			**X**			
17	Technical	Deformation of receiver due to high temperature						**X**
18	Technical	Deformation of receiver due to high pressure						**X**
19	Technical	Improper boiler installation				**X**		
20	Technical	Improper installation of pumps			**X**			
21	Technical	Improper installation of valves			**X**			
22	Technical	Improper piping installation				**X**		
23	Technical	Failure in water treatment unit			**X**			
24	Technical	Insufficient insulation				**X**		
25	Technical	Improper fittings installation				**X**		
26	Technical	Incorrect placement of the condenser				**X**		
27	Technical	Insufficient gas purification in deaerator unit						**X**
28	Technical	Too low or too high inlet steam flow rate						**X**
29	Technical	Too low or too high inlet steam temperature						**X**
30	Technical	Too low or too high inlet steam pressure						**X**
31	Technical	Too low or too high exhaust vapor flow rate						**X**

Table C.1 (continued)

32	Technical	Too low or too high exhaust vapor temperature						**X**
33	Technical	Too low or too high exhaust vapor pressure						**X**
34	Technical	Improper heliostat erection				**X**		
35	Technical	High tower construction problem				**X**		
36	Technical	Wireless communication problems of heliostats					**X**	
37	Technical	Connection problems with main software					**X**	
38	Technical	Communication problems of receiver and heliostats					**X**	
39	Technical	Problem of receiver otomation					**X**	
40	Technical	Heliostat concentration problem						**X**
41	Technical	Mirror reflection failure						**X**
42	Technical	Excessive heating in thermal system components						**X**
43	Technical	Temperature sensor problem						**X**
44	Technical	Pressure sensor problem						**X**
45	Technical	Flow rate measurement equipment problem						**X**
46	Technical	Increasing cooling water temperature						**X**
47	Social	Irregularity in the assembly bands				**X**		
48	Social	Irregular cabling				**X**		
49	Social	Marking of high pressure and high temperature equipments				**X**		
50	Social	Leaving open the electrical cabinet doors						**X**
51	Social	The lack of security alerts in the assembly area				**X**		
52	Social	Not using safety equipment when working on towers				**X**		
53	Social	The lack of security alerts in the tower and thermal equipment field						**X**
54	Economic	The excessive increase in material prices			**X**			
55	Political	Decline in government incentives for solar energy	**X**					
56	Economic	Extreme weather condition						**X**
57	Economic	Long term solar irradiation decrease						**X**
58	Political	Procedurel delay of electricity production licence						**X**
59	Economic	Delay in procurement of materials from overseas supplier			**X**			
60	Economic	Delay in production of heliostat components			**X**			
61	Political	Possible delay in construction			**X**			
62	Economic	Strict regulation on custom while procurement of imported equipments			**X**			
63	Economic	Heliostat mirror damage while transferring			**X**	**X**		
64	Economic	Partner bankruptcy			**X**			**X**
65	Social	Skilled labour anavailability	**X**	**X**	**X**	**X**	**X**	**X**
66	Technical	Lower yield						**X**
67	Technical	Difficult acces to site (like desert area)				**X**	**X**	**X**

Table C.1 (continued)

68	Technical	Bad weather condition during construction				**X**		
69	Technical	Deterioration of the heliostat carrier crane in the assembly area				**X**		
70	Economic	Loss of manpower from any cause				**X**		
71	Technical	Failure of measuring instruments						**X**
72	Technical	Failure of assembly instruments				**X**		
73	Technical	Failures in production patterns			**X**			
74	Technical	Inadequate quality control			**X**			
75	Technical	Material loss during installation				**X**		
76	Economic	Field floor distortion				**X**		
77	Technical	Revision need for wrong designed components		**X**				
78	Technical	Problem in signaling in abnormal cases						**X**
79	Social	Lack of training of technical employees				**X**		
80	Technical	Corruption of the calibration device						**X**
81	Technical	Excessive dust on reflective mirror						**X**
82	Technical	Erosion of the surface paint of thermal components						**X**
83	Social	Insufficiently ventilated indoor assembly places				**X**		
84	Technical	Wrong welding in tower construction				**X**		
85	Social	Personel training about health and safety				**X**		**X**
86	Economic	Number of missing fire extinguisher						**X**
87	Economic	Natural disasters				**X**		**X**
88	Technical	Missing grounding in electrical equipment					**X**	**X**
89	Social	Personal protective equipment usage by employees				**X**		
90	Social	Lack of Information about the harm of used chemicals in water treatment unit						**X**
91	Economic	The warranty period constraints of purchased products			**X**			

APPENDIX D

Table D.1: Full risk breakdown structure.

CSP TOWER PROJECT					
1. Conceptual Design	**2. System Components Design**	**3. Production and Supply of System Components**	**4. Assembly**	**5. Hardware and Software Integration**	**6. Commisioning and System Tests**
1.1 Field Settlement Plan	2.1 Heliostat Design	3.1. Heliostat components Production	4.1 Heliostat erection	5.1. Heliostat hardware and software integration	6.1. Concentration tests
1.1.1 Miscalculation in field settlement	2.1.1 Faulty heliostat design	3.1.1 Unproper heliostat concrete reinforcement	4.1.1 Improper heliostat erection	5.1.1 Wireless communication problems of heliostats	6.1.1 Deformation of receiver due to high temperature
1.1.2 Shadow effect	2.1.2 Unproper heliostat concrete reinforcement	3.1.2 Backlash in gearbox	4.1.2 Irregularity in the assembly bands	5.1.2 Connection problems with main software	6.1.2 Deformation of receiver due to high pressure
1.2 Process Flow Diagram	2.1.3 Revision need for wrong designed components	3.1.3 Error while producing interface in desired precision	4.1.3 The lack of security alerts in the assembly area	5.1.3 Communication problems of receiver and heliostats	6.1.3 Heliostat concentration problem
1.2.1 Incorrect drawing in proces flow diagram	2.1.4 Skilled labour anavailability	3.1.4 Error while producing torque tube in desired precision	4.1.4 Irregular cabling	5.1.4 Skilled labour anavailability	6.1.4 Mirror reflection failure
1.3 System modelling and simulation	2.2 Tower Design	3.1.5 Problem in the press when producing composite arms	4.1.5 Heliostat mirror damage while transferring	5.1.5 Difficult acces to site	6.1.5 Excessive dust on reflective mirror
1.3.1 Error in modelling and simulation programmes	2.2.1 Wrong Tower Design	3.1.6 Production error in the desired reflection ratio of mirrors	4.1.6 Skilled labour anavailability	5.1.6 Missing grounding in electrical equipment	6.2. Reflection tests
1.3.2 Decline in government incentives for solar energy	2.2.2 Revision need for wrong designed components	3.1.7 Failure in production of control box	4.1.7 Difficult acces to site	5.2. Receiver&Thermal proces hardware and software integration	6.2.1 Deformation of receiver due to high temperature
1.3.3 Skilled labour anavailability	2.2.3 Skilled labour anavailability	3.1.8 Delay in production of heliostat components	4.1.8 Bad weather condition during construction	5.2.1 Problem of receiver otomation	6.3. Temperature test
	2.3 Receiver&Thermal equipments design	3.1.9 The excessive increase in material prices	4.1.9 Deterioration of the heliostat carrier crane in the assembly area	5.2.2 Connection problems with main software	6.3.1 Deformation of receiver due to high temperature
	2.3.1 Design error in Receiver&Thermal equipments	3.1.10 Delay in procurement of materials from overseas supplier	4.1.10 Loss of manpower from any cause	5.2.3 Communication problems of receiver and heliostats	6.3.2 Too low or too high inlet steam temperature
	2.3.2 Revision need for wrong designed components	3.1.11 Possible delay in construction	4.1.11 Failure of assembly instruments	5.2.4 Skilled labour anavailability	6.3.3 Too low or too high exhaust vapor temperature

Table D.1 (continued)

2.3.3 Skilled labour anavailability	3.1.12 Strict regulation on custom while procurement of imported equipments	4.1.12 Material loss during installation	5.2.5 Difficult acces to site	6.3.4 Temperature sensor problem
2.4 Software design	3.1.13 Heliostat mirror damage while transferring	4.1.13 Field floor distortion	5.2.6 Missing grounding in electrical equipment	6.3.5 Increasing cooling water temperature
2.4.1 Design error in software	3.1.14 Partner bankruptcy	4.1.14 Lack of training of technical employees	5.3. Integration with central software	6.4. Pressure tests
2.4.2 Revision need for wrong designed components	3.1.15 Skilled labour anavailability	4.1.15 Insufficiently ventilated indoor assembly places	5.3.1 Connection problems with main software	6.4.1 Deformation of receiver due to high pressure
2.4.3 Skilled labour anavailability	3.1.16 Failures in production patterns	4.1.16 Personel training about health and safety	5.3.2 Communication problems of receiver and heliostats	6.4.2 Too low or too high inlet steam pressure
	3.1.17 Inadequate quality control	4.1.17 Natural disasters	5.3.3 Skilled labour anavailability	6.4.3 Too low or too high exhaust vapor pressure
	3.1.18 The warranty period constraints of purchased products	4.1.18 Personal protective equipment usage by employees	5.3.4 Difficult acces to site	6.4.4 Pressure sensor problem
	3.2. Tower	4.2 Tower erection	5.3.5 Missing grounding in electrical equipment	6.5. Trial production
	3.2.1 Oscillation in the tower	4.2.1 High tower construction problem		6.5.1 Too low or too high inlet steam flow rate
	3.2.2 The excessive increase in material prices	4.2.2 Not using safety equipment when working on towers		6.5.2 Too low or too high exhaust vapor flow rate
	3.2.3 Delay in procurement of materials from overseas supplier	4.2.3 Skilled labour anavailability		6.5.3 Flow rate measurement equipment problem
	3.2.4 Possible delay in construction	4.2.4 Difficult acces to site		6.5.4 Lack of Information about the harm of used chemicals in water treatment unit
	3.2.5 Strict regulation on custom while procurement of imported equipments	4.2.5 Bad weather condition during construction		6.6. Thermal efficiency tests
	3.2.6 Partner bankruptcy	4.2.6 Deterioration of the heliostat carrier crane in the assembly area		6.6.1 Excessive heating in thermal system components
	3.2.7 Skilled labour anavailability	4.2.7 Loss of manpower from any cause		6.6.2 The lack of security alerts in the tower and thermal equipment field

Table D.1 (continued)

3.2.8 Failures in production patterns	4.2.8 Failure of assembly instruments		6.7. Hot cycle efficiency analysis
3.2.9 Inadequate quality control	4.2.9 Material loss during installation		6.7.1 Erosion of the surface paint of thermal components
3.2.10 The warranty period constraints of purchased products	4.2.10 Field floor distortion		6.8. Total system test
3.3. Receiver and Thermal equipments	4.2.11 Lack of training of technical employees		6.8.1 Insufficient gas purification in deaerator unit
3.3.1 Improper installation of pumps	4.2.12 Insufficiently ventilated indoor assembly places		6.8.2 Leaving open the electrical cabinet doors
3.3.2 Improper installation of valves	4.2.13 Personel training about health and safety		6.8.3 Extreme weather condition
3.3.3 Failure in water treatment unit	4.2.14 Natural disasters		6.8.4 Long term solar irradiation decrease
3.3.4 The excessive increase in material prices	4.2.15 Personal protective equipment usage by employees		6.8.5 Procedurel delay of electricity production licence
3.3.5 Delay in procurement of materials from overseas supplier	4.2.16 Wrong welding in tower construction		6.8.6 Partner bankruptcy
3.3.6 Possible delay in construction	4.3 Receiver&Thermal equipments placement		6.8.7 Skilled labour anavailability
3.3.7 Strict regulation on custom while procurement of imported equipments	4.3.1 Improper boiler installation		6.8.8 Lower yield
3.3.8 Partner bankruptcy	4.3.2 Improper piping installation		6.8.9 Difficult acces to site
3.3.9 Skilled labour anavailability	4.3.3 Insufficient insulation		6.8.10 Failure of measuring instruments
3.3.10 Failures in production patterns	4.3.4 Improper fittings installation		6.8.11 Problem in signaling in abnormal cases
3.3.11 Inadequate quality control	4.3.5 Irregular cabling		6.8.12 Corruption of the calibration device
3.3.12 The warranty period constraints of purchased products	4.3.6 Skilled labour anavailability		6.8.13 Personel training about health and safety
	4.3.7 Difficult acces to site		6.8.14 Number of missing fire extinguisher

Table D.1 (continued)

4.3.8 Bad weather condition during construction	6.8.15 Natural disasters
4.3.9 Deterioration of the heliostat carrier crane in the assembly area	6.8.16 Missing grounding in electrical equipment
4.3.10 Loss of manpower from any cause	
4.3.11 Failure of assembly instruments	
4.3.12 Material loss during installation	
4.3.13 Field floor distortion	
4.3.14 Lack of training of technical employees	
4.3.15 Insufficiently ventilated indoor assembly places	
4.3.16 Personel training about health and safety	
4.3.17 Natural disasters	
4.3.18 Personal protective equipment usage by employees	
4.3.19 Marking of high pressure and high temperature equipment	
4.3.20 Incorrect placement of the condenser	

APPENDIX E

Table E.1: Risk breakdown structure number of identified technical risks.

Number	RBS number	Technical Risks	Probability	Impact	Risk Level
1	1.1.1.	Miscalculation in field settlement	1	5	5
2	1.1.2.	Shadow effect	1	4	4
3	1.2.1.	Incorrect drawing in proces flow diagram	1	4	4
4	1.3.1.	Error in modelling and simulation programmes	3	4	12
5	2.1.1.	Faulty Heliostat design	1	5	5
6	2.2.1.	Wrong tower design	1	5	5
7	2.3.1.	Design error in Receiver&Thermal equipments	1	5	5
8	2.4.1.	Design error in software	2	5	10
9	2.1.2.	Unproper heliostat concrete reinforcement	3	4	12
10	3.1.2.	Backlash in gearbox	1	4	4
11	3.1.3.	Error while producing interface in desired precision	1	4	4
12	3.1.4.	Error while producing torque tube in desired precision	2	4	8
13	3.1.5.	Problem in the press when producing composite arms	2	4	8
14	3.1.6.	Production error in the desired reflection ratio of mirrors	2	4	8
15	3.1.7.	Failure in production of control box	3	4	12
16	3.2.1.	Oscillation in the tower	2	4	8
17	6.1.1.	Deformation of receiver due to high temperature	2	5	10
18	6.1.2.	Deformation of receiver due to high pressure	2	5	10
19	4.3.1.	Improper boiler installation	2	5	10
20	3.3.1.	Improper installation of pumps	2	5	10
21	3.3.2.	Improper installation of valves	2	5	10
22	4.3.2.	Improper piping installation	2	5	10
23	3.1.7.	Failure in water treatment unit	2	4	8
24	4.3.3.	Insufficient insulation	2	5	10
25	4.3.4.	Improper fittings installation	2	5	10
26	4.3.20.	Incorrect placement of the condenser	2	3	6
27	6.8.1.	Insufficient gas purification in deaerator unit	2	3	6
28	6.5.1.	Too low or too high inlet steam flow rate	2	5	10
29	6.3.2.	Too low or too high inlet steam temperature	2	5	10
30	6.4.2.	Too low or too high inlet steam pressure	2	5	10

Table E.1 (continued)

32	6.3.3.	Too low or too high exhaust vapor temperature	2	5	10
33	6.4.3.	Too low or too high exhaust vapor pressure	2	5	10
34	4.1.1.	Improper heliostat erection	3	5	15
35	4.2.1.	High tower construction problem	3	5	15
36	5.1.1.	Wireless communication problems of heliostats	5	5	25
37	5.1.2.	Connection problems with main software	2	5	10
38	5.1.3.	Communication problems of receiver and heliostats	4	5	20
39	5.2.1.	Problem of receiver otomation	2	5	10
40	6.1.3.	Heliostat concentration problem	3	3	9
41	6.1.4.	Mirror reflection failure	1	4	4
42	6.6.1.	Excessive heating in thermal system components	2	5	10
43	6.3.4.	Temperature sensor problem	2	5	10
44	6.4.4.	Pressure sensor problem	2	5	10
45	6.5.3.	Flow rate measurement equipment problem	2	5	10
46	6.3.5.	Increasing cooling water temperature	2	5	10
66	6.8.8.	Lower yield	2	5	10
67	6.8.9.	Difficult acces to site (like desert area)	4	4	16
68	4.3.8.	Bad weather condition during construction	3	4	12
69	4.3.9.	Deterioration of the heliostat carrier crane in the assembly area	3	3	9
71	6.8.10.	Failure of measuring instruments	3	4	12
72	4.3.11.	Failure of assembly instruments	2	4	8
73	3.3.10.	Failures in production patterns	2	3	6
74	3.3.11.	Inadequate quality control	3	5	15
75	4.3.11.	Material loss during installation	3	3	9
77	2.1.3.	Revision need for wrong designed components	3	3	9
78	6.8.11.	Problem in signaling in abnormal cases	5	5	25
80	6.8.12.	Corruption of the calibration device	1	5	5
81	6.1.5.	Excessive dust on reflective mirror	5	4	20
82	6.7.1.	Erosion of the surface paint of thermal components	4	4	16
84	4.2.16.	Wrong welding in tower construction	2	4	8
88	6.8.16.	Missing grounding in electrical equipment	2	4	8

APPENDIX F

Table F.1: Probability, impact and risk level values of technical risks.

			In which phase(s) does the risk cause concern?								
Number	**RBS Number**	**Technical Risks**	**Conceptual Design**	**System Components Design**	**Production and Supply of System Components**	**Assembly**	**Hardware and Software Integration**	**Commisioning and System Test**	**Probability**	**Impact**	**Risk Level**
1	**1.1.1.**	Miscalculation in field settlement	**X**						1	5	5
2	**1.1.2.**	Shadow effect	**X**						1	4	4
3	**1.2.1.**	Incorrect drawing in proces flow diagram	**X**						1	4	4
4	**1.3.1.**	Error in modelling and simulation programmes	**X**						3	4	12
5	**2.1.1.**	Faulty Heliostat design		**X**					1	5	5
6	**2.2.1.**	Wrong tower design		**X**					1	5	5
7	**2.3.1.**	Design error in Receiver&Thermal equipments		**X**					1	5	5
8	**2.4.1.**	Design error in software		**X**					2	5	10
9	**2.1.2.**	Unproper heliostat concrete reinforcement		**X**	**X**				3	4	12
10	**3.1.2.**	Backlash in gearbox			**X**				1	4	4
11	**3.1.3.**	Error while producing interface in desired precision			**X**				1	4	4
12	**3.1.4.**	Error while producing torque tube in desired precision			**X**				2	4	8
13	**3.1.5.**	Problem in the press when producing composite arms			**X**				2	4	8
14	**3.1.6.**	Production error in the desired reflection ratio of mirrors			**X**				2	4	8
15	**3.1.7.**	Failure in production of control box			**X**				3	4	12
16	**3.2.1.**	Oscillation in the tower			**X**				2	4	8
17	**6.1.1.**	Deformation of receiver due to high temperature						**X**	2	5	10
18	**6.1.2.**	Deformation of receiver due to high pressure						**X**	2	5	10
19	**4.3.1.**	Improper boiler installation				**X**			2	5	10
20	**3.3.1.**	Improper installation of pumps			**X**				2	5	10
21	**3.3.2.**	Improper installation of valves			**X**				2	5	10
22	**4.3.2.**	Improper piping installation				**X**			2	5	10

Table F.1 (continued)

23	**3.1.7.**	Failure in water treatment unit			**X**				2	4	8
24	**4.3.3.**	Insufficient insulation				**X**			2	5	10
25	**4.3.4.**	Improper fittings installation				**X**			2	5	10
26	**4.3.20.**	Incorrect placement of the condenser				**X**			2	3	6
27	**6.8.1.**	Insufficient gas purification in deaerator unit						**X**	2	3	6
28	**6.5.1.**	Too low or too high inlet steam flow rate						**X**	2	5	10
29	**6.3.2.**	Too low or too high inlet steam temperature						**X**	2	5	10
30	**6.4.2.**	Too low or too high inlet steam pressure						**X**	2	5	10
31	**6.5.2.**	Too low or too high exhaust vapor flow rate						**X**	2	5	10
32	**6.3.3.**	Too low or too high exhaust vapor temperature						**X**	2	5	10
33	**6.4.3.**	Too low or too high exhaust vapor pressure						**X**	2	5	10
34	**4.1.1.**	Improper heliostat erection				**X**			3	5	15
35	**4.2.1.**	High tower construction problem				**X**			3	5	15
36	**5.1.1.**	Wireless communication problems of heliostats					**X**		5	5	25
37	**5.1.2.**	Connection problems with main software					**X**		2	5	10
38	**5.1.3.**	Communication problems of receiver and heliostats					**X**		4	5	20
39	**5.2.1.**	Problem of receiver otomation					**X**		2	5	10
40	**6.1.3.**	Heliostat concentration problem						**X**	3	3	9
41	**6.1.4.**	Mirror reflection failure						**X**	1	4	4
42	**6.6.1.**	Excessive heating in thermal system components						**X**	2	5	10
43	**6.3.4.**	Temperature sensor problem						**X**	2	5	10
44	**6.4.4.**	Pressure sensor problem						**X**	2	5	10
45	**6.5.3.**	Flow rate measurement equipment problem						**X**	2	5	10
46	**6.3.5.**	Increasing cooling water temperature						**X**	2	5	10
66	**6.8.8.**	Lower yield						**X**	2	5	10
67	**6.8.9.**	Difficult acces to site (like desert area)				**X**	**X**	**X**	4	4	16
68	**4.3.8.**	Bad weather condition during construction				**X**			3	4	12
69	**4.3.9.**	Deterioration of the heliostat carrier crane in the assembly area				**X**			3	3	9
71	**6.8.10.**	Failure of measuring instruments						**X**	3	4	12
72	**4.3.11.**	Failure of assembly instruments				**X**			2	4	8

Table F.1 (continued)

73	**3.3.10.**	Failures in production patterns			**X**				2	3	6
74	**3.3.11.**	Inadequate quality control			**X**				3	5	15
75	**4.3.11.**	Material loss during installation				**X**			3	3	9
77	**2.1.3.**	Revision need for wrong designed components		**X**					3	3	9
78	**6.8.11.**	Problem in signaling in abnormal cases						**X**	5	5	25
80	**6.8.12.**	Corruption of the calibration device						**X**	1	5	5
81	**6.1.5.**	Excessive dust on reflective mirror						**X**	5	4	20
82	**6.7.1.**	Erosion of the surface paint of thermal components						**X**	4	4	16
84	**4.2.16.**	Wrong welding in tower construction				**X**			2	4	8
88	**6.8.16.**	Missing grounding in electrical equipment					**X**	**X**	2	4	8

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2008-2009: Fall Semester, List of Honors

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