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China's Energy Investment in Africa and the Sustainable Energy Development of the Continent

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Author's declaration

No portion of the work referred to in this thesis has been submitted in support of an application for another degree or qualification of this or any other university or other institute of learning.

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ABSTRACT OF THESIS submitted by:
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Achieving a sustainable energy future in Africa will require massive and unprecedented investments in energy infrastructure. This thesis aims to determine whether a significant part of this investment could come from China. The thesis analyses several scenarios of energy futures in Africa both in presence and in absence of energy access and climate mitigation policies. It also examines China's current energy investments in Africa and their trends. The focus is on non-fossil electricity generation, where energy investment needs are largest and the situation with China's investments is clearer than in other sectors.

Most scenarios predict the level of investment in non-fossil electricity generation needed for achieving sustainable energy objectives growing from the present level under 10 bln USD/year to 20-30 bln USD/year by 2030. China's current investment in this area of 1.4-3.5 bln USD/year may grow to 10-20 bln/USD year even under conservative projections of its growth rates. Thus, it is likely that China's investment will make a notable contribution to achieving Africa's sustainable energy goals. However, this will occur only if China's investment is re-oriented from large-scale hydro power plants to smaller wind, solar and bio-energy facilities, if investments in generation capacity is supplemented by equally ambitious investments in transmission and generation capacities, if the geographic base of investment is broadened from the current resource-rich countries, and if private investment strategies are aligned with loans and aid programs. Modifications of regulatory frameworks and approaches on both China's and Africa's side may be required to meet these needs.

Keywords: Africa, China's FDI, Energy Investment

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List of Abbreviations

AfDB-African Development Bank

BOOT-Build, own, operate, transfer

BRIC-Brazil, Russia, India and China

EDI-Energy Development Index

FDI-Foreign Direct Investment

FOCAC-Forum on China-Africa Cooperation

GEA-Global Energy Assessment

GHG-Greenhouse Gas

IFDI-Inward FDI

MDG-Millennium Development Goals

OFDI-Outward FDI

PPI-Private participation in infrastructure

PPP-Public-Private-Partnerships

MOFCOM-Ministry of Commerce, People's Republic of China

SSA-Sub-Saharan Africa

UNIDO-United Nations Industrial Development Organization

UNCTAD-United Nations Conference on Trade and Development

WEO-World Energy Outlook

1. Introduction

1.1 Background

Limited access to modern and affordable energy services is seriously impeding social and economic growth in developing countries, particularly in sub-Saharan Africa and some parts of Asia. The provision of affordable, reliable and cleaner energy services are at the core of tackling global development challenges and is potentially connected with most Millennium Development Goals (MDGs).

The Energy Development Index (EDI), which is established by World Energy Outlook (WEO) to aid policy makers in tracking progress towards providing modern energy access, includes relevant indicators relating to the current condition of 80 countries in terms of modern energy service access, renewable energy adoption and energy efficiency. The index ranking has shown that while most developing countries in Asia and Latin America have witnessed improvement in the past few years, sub-Saharan Africa (SSA) as a region performs the least well, and is still undergoing a worsening trend, even until around 2025 (WEO 2012).

To address the energy poverty issue, a comprehensive set of goal was put forth to the international community by the United Nations Secretary-General's Advisory Group on Energy and Climate Change (AGECC, 2010) under the initiative of Sustainable Energy for All. The initiative set up three major critical targets, including

- Providing universal access to modern energy services
- Doubling the share of renewable energy in the global energy mix
- Doubling the global rate of improvement in energy efficiency by 2030

The initiative not only set up a common goal but also presented the challenge towards the international community as a whole. The African Development Bank (AfDB) estimated that in order to implement its scenario of universal access to reliable and increasingly cleaner electric power in all the 53 countries in Africa by 2030, a total investment of US$ 547 billion is required (AfDB 2008). However, as implied by AfDB (2008), the total funding in the energy sector in sub-Saharan Africa has averaged only about US$2 billion every year, in contrast with annual need of $27 billion.

On the other hand, China has been one of the emerging Foreign Direct Investment (FDI) contributors to Africa, especially the sub-Saharan Africa region. The “go-out” strategy, which was established in 2001 by the Chinese government, provided a guideline for Chinese companies to invest abroad and implement merge and acquisition (M&A), which aligns with IMF’s definition of FDI, as “a cross-border investment in which the direct investor acquires a lasting interest in a direct investment enterprise” (IMF 2003).

There have been controversies (Brautigam 2010; Mol 2010; Taylor 2007; Zweig and Bi 2005) on China’s growing Outward Foreign Direct Investment (OFDI) in terms of motivation and impacts, especially around the natural resource grab issue. In the past few decades, the scale and sectorial distribution of China’s FDI have undergone a gradual transformation. Such transformation has been influenced by China’s increasing domestic demand driven by the growing economy, the political and trade relationship between China and host countries, the resource abundance and economic development of the host countries, etc. With China’s stable growth on one hand and the African continent’s emerging economic growth on the other, it is expected that China’s FDI in Africa will further increase (UNIDO 2009) and some transformation such as the increasing demand for renewable energy investment is expected to take place.

However, most of the past studies have focused on the general image of China’s FDI or the traditional form of energy investment in oil and gas, little literature has focused specifically on China’s sustainable energy investment or elaborated on the potential impact that China’s energy investment could bring about to the host country, in terms of local sustainable energy system development.

Despite of the fact that Africa is lagging behind most regions of the world in terms of access to modern energy, it is endowed with abundant and untapped energy resources including renewable energy. The *Scaling up Renewable Energy in Africa* (2009) report implied that one big challenge for African countries is to urge more inclusion of renewable energy in the south-south investment partnerships, which is a win-win strategy for the involved partners. Among the potential partners, China and India are the most promising investors, both of whom having been rapidly expanding their renewable energy manufacturing base in the recent few years (UNIDO 2009).

China's development in energy empowerment has been witnessed by the world. Within 30 years' continual efforts, the country has made universal electrification possible. Renewable energy manufacturing has also been increasing exponentially, especially in the past few years. Considering China's renewable energy strategy in its economic development master plan and its continual commitment in the aid and investment on the African continent, it is logical to expect China's more involvement in Africa's sustainable energy development.

At the fourth Forum on China-Africa Cooperation (FOCAC) in 2009, Chinese premier Wen Jiabao at the time announced that China would build up 100 clean energy projects across the continent focusing on solar power, biogas and small hydropower. Although some of China's renewable energy producers have stepped in the African market before 2009, most of the projects took place in the form of large hydropower plant construction. Other common investment projects include railway, highway or bridge infrastructure construction. If the previous individual projects could be considered as an early exploration of the market, the high-profile commitment on small-scale renewable energy projects is expected to distinguish a break from China's traditional investment in Africa.

Considering that it has only been three years since Premier Wen's 100-project promise, the achievement and results of this master plan is yet to be tested, especially in comparison with the traditional investment pattern. The change of China's central leadership in early 2013 and the strengthening BRIC partnership have also brought the "China in Africa" topic into a more dynamic context. In a longer term, it is believed that China's efforts in providing aid and making investment on the African continent would be "less a one-way offering of alms (as Chinese premier Zhou Enlai explained in 1964), but more a practical investment in a mutually profitable future" (Brautigam 2009). This study would be scoped in the energy sector to discover the role of China's FDI in this potentially mutual profitable future.

1.2 Research aim, questions and objectives

This research aims at examining the effects of China's OFDI in Africa, especially the SSA region, on sustainable energy development. This research aims to answer the key question:

Does China's energy investment in Africa contribute to developing a sustainable energy system in the region, and to what extent?

In order to approach this question, the following sub-questions are supposed to be answered in the research process:

- What is the gap between the current energy system in Africa and the 2030 goal proposed by the Sustainable4All initiative and to what extent is China's investment contributing to achieving these goals at present and likely to contribute in the future?
- How significant is China's FDI in Africa and how is it distributed among different sectors and regions?
- How does China's energy investment in Africa compare to Africa's energy development needs?

Within the scope of the above aim, the study has the following objectives:

- Clarify the concept and parameters of sustainable energy systems in Africa and the investment needs associated with these objectives
- Collect and analyze data of historical, current and potential (in plan) China's FDI in Africa, that contributes to the energy sector
- Evaluate the significance of China's contribution to sustainable energy development in Africa both now and potentially in the future
- Compare these data with the investment needs of the African continent to achieve sustainable energy objectives and evaluate the significance of China's current and potential role in the future

1.3 Research Approach

This research is largely based on the analysis of existing literature (statistical data, scholarly studies and public documents) with some calculations performed by the author to achieve research objectives.

This thesis is structured as follows. The second chapter contains a literature review that was carried out before data collection and data analysis design. A thorough literature review on China's FDI, especially in Africa is necessary to understand the motivation of China's FDI and the changes that have taken place in the past few decades, as well as the potential trend that would come up in the future. Data and analysis that appeared in previous studies may also be utilized for comparison with the current analysis result.

The third chapter contains the description of the research methods that are adopted to meet the research objectives and the data sources that are at the core of data collection and analysis in this study. The fourth chapter lays out the collected and analyzed data results in three dimensions: the energy needs of Africa, the profile of China's FDI in Africa, as well as China's energy investment in Africa. A follow-up discussion would try to find out China's role in contributing to financing the gap towards Africa's sustainable energy development. The last chapter is a conclusion of the research findings.

2. Literature review

The topic "China in Africa" has received significant and controversial attention from around the world. However, there has been very little academic or professional literature directly addressing the role of China's aid and investment in energy sustainability. The exceptions are the two World Wildlife Foundation's (WWF) reports (Conrad *et al*. 2011; Jensen *et al*. 2012), which focus specifically on China's renewable energy investment in Africa. One (Conrad *et al*. 2011) analyzed the motives behind China's renewable energy investment in Africa and contains a SWOT analysis based on four countries' case studies to examine strengths, weaknesses, opportunities and threats to both China and Africa in China's renewable energy engagement with the continent. The other (Jensen *et al*. 2012) presented the renewable energy development potential of Africa and the challenges in China's renewable energy investment, and proposed the opportunities for Norway to get involved in the renewable energy development on the Africa continent.

Other than these two WWF reports, the existing scholarly literature that is relevant to this study covers the following areas:

- China's investment in Africa and associated issues, including the motivation of China's investment, the economic, political and social impact of China's investment
- Energy challenges of Africa, sustainable energy development scenarios and the ways to achieve them

The review of the literature covering the above areas is aimed at understanding the nature of China's FDI, especially the Outward FDI towards Africa, as well as presenting the potential trend that would come up in the future, at the nexus of China's FDI engagement and green economy development strategy.

2.1 History of China's "going out"

In most of the analysis of China's FDI in Africa, statistics about China's high-rate and stable growth of Gross Domestic Product (GDP) in the past two decades are presented to demonstrate China's economic development, which leads to the discussion on China's seek for natural resources and energy supplies around the world to fuel its domestic appetite. Indeed, China has maintained a GDP growth rate above 8% in the past ten years （World Bank 2013）, even amid the global financial crisis around 2008 and 2009. In 2010, IEA suggested that China had overtaken the U.S. in 2009 to become the world's largest energy consumer (IEA 2010). Although Chinese officials refused to accept such claims (Watkins 2010), the trend of increasing energy demand is undeniable. Looking into the significant events and policy establishment in China's history, it is true to some extent that the encouragement of outflow FDI and the country's energy demand/supply profile are inter-connected. It is logical to claim that the country needs to keep seeking for natural resources and energy supply to fuel its fast development and the staggering appetite for energy to some extent explains the country's expanding investment abroad.

Zha (2006), a Chinese expert in international relations and energy issues in China, made a detailed tracking of China's transformation from a country reliant on Soviet Union's technology and resource, to a self-supplied oil export country, until becoming a major oil import state. After the Sino-Soviet split in the early 1960s, China had once achieved self-sufficient energy production, especially after the discovery of DaQing Oil Field in 1959. It was in 1993 that China became a net importer of oil products and 1996, a net importer of crude oil (Zha 2006). In 2011, IEA projected that China would become the largest net oil importer by 2020 (WEO, 2011).

Turning to the FDI side, in 2001, the "Go out" strategy was established by the Chinese authority, which is a significant step amid the "reform and opening-up" development path of China since 1978. The "Go out" strategy" provided a guideline for Chinese companies, especially state owned enterprises (SOEs) to invest abroad. According to IMF's definition, foreign direct investment (FDI) is "a cross-border investment in which the direct investor acquires a lasting interest in a direct investment enterprise" (IMF 2003), which explains the behavior of Chinese companies' "Going out". Although initially, state-owned enterprises are the dominant player in China's FDI in Africa thanking to the strong policy and financing support from the government, the emerging involvement of private enterprises, especially in the manufacturing sector, has been changing the landscape of China's OFDI gradually. This is somehow an encouraging trend for clean energy manufacturers to explore the energy market shares and compete with state-owned tycoons with their expertise advantage.

The primary rationale behind the "Go out" strategy was to make a natural transition from purely promoting inward FDI for almost a decade towards promoting both inward and outward FDI, and increase the overseas presence of Chinese companies, as well as to deal with the country's domestic oversupply. At the same time, for large SOEs such as China Petoroleum (CNPC), SinoPec (CPCC) and China National Offshore Oil Cop (CNOOC), the "Go out" strategy provided them with a guideline and opportunity to go abroad and acquire concession right in foreign oil fields. In face of the growing overseas investment made by large natural resource industry SOEs, the original economic rationale has been less interpreted by foreign stakeholders. Instead, the natural resource grab cap has been given to Chinese FDI, explained with more political justifications.

2.2 Rationale behind the increase of China's outflow FDI into Africa

The Sino-African relationship has a long story to tell, which can be traced back to the 1960s and 1970s, when the relationship was more "political and ideological" (Mol 2011) i.e. based on the spread of communism ideology. But it is only until the recent decade that the trade ties have been enhanced, with energy and infrastructure as the major targeted sectors. Even in the 1990s, China was not yet on the top list of the trade partners with Africa. It is only in the recent decade that China's ascendance and its increasing investment in Africa have started to receive more international attention, in terms of both political and economic implications.

In order to justify or to critique China's increasing FDI flow into Africa, many studies were carried out, both qualitatively and quantitatively. The qualitative discussions can be subjective, depending on how the interview or survey had been conducted as well as where the arguments were collected, while the ones built up on existing theory frameworks, tend to be more objective and critical. The quantitative analysis such as utilizing regression and mathematical models to evaluate the relationships and the determinants provided seemingly a more objective approach to decompose a relatively subjective issue, although their rigor naturally depends on how the regression parameters were defined by the author. A summary of some of the major perspectives on the motives behind China's increasing FDI has been presented in Table 2.1.

In broader terms, the motives behind China's OFDI towards Africa can be divided into two categories: resource-oriented and market-oriented, or some literature also defined it as "market-seeking" and "non market-seeking" (Ayanwale *et al*. 2007). Considering the history and origin of China's "Go out" strategy, it is not surprising that the support for "resource-oriented" determinant argument has dominated the existing literature on China's OFDI in Africa (Hong and Sun 2006; Taylor 2009; Zeig and Bi 2005).

Table 2. 1 Perspectives on motives of China's FDI in Africa

Motives	Perspectives	Resources
Economic	The similarity between economy levels of the host and donor countries would enhance the FDI flow	Cheng and Ruan 2004
	China's FDI and recipient country's GDP, bidirectional influence exists	Xiao and Shen 2002
		Alon 2012
	Local market size is important	Claassen *et al*. 2011
	Domestic supply driven	Conrad 2012
Political	Weak governance and high corruption level correlates with high FDI flow	Alon 2012
	China has a right to pursue natural resources through market	Zweig and Bi 2005
	Natural resource seeking but not limited to oil	Taylor 2004
	Natural resource still important, but market does matter	Hong and Sun 2004

In addition, the mode of China's large infrastructure deals with Africa, where the repayment of the loan for infrastructure development is made in terms of natural resources such as oil and gas, has been referred to as "Angola mode" (World Bank 2008). Such deals are mostly used for countries that could not provide adequate financial guarantees, thus the natural resource exploitation is packed along with infrastructure development in the investment deal. The 2008 World Bank report on China's infrastructure financier role in sub-Saharan Africa documented eight resource-backed deals of this kind, worth more than US$3 billion covering petroleum, mineral resources and agricultural products.

Among quantitative analysis, Kolstad and Wiig (2008) and Alon (2012) looked into the determinants of China's investment in Africa, applying both descriptive statistics and the economic models to test the relevance of proposed determinants. Some determinants which are the independent variables in the models include per capita GDP, distance, cultural distance, political right, and governance index, etc. Conversions have been made to interpret factors such as "free from corruption" and "cultural distance" into comparable quantitative data, for systematic comparisons is also replicable for the study on certain countries. The results confirmed that the direction of China's FDI in Africa is well explained by economic fundamentals and resource richness of the recipient countries" aligning with many previous studies' perspectives. However, Alon (2012) also proposed a different perspective on the "resource-oriented" determinant. The result shows that while China's investment is more closely focused on African countries that are rich in metal and ore resources than the rest of the world, its engagement with fuel resource (such as oil and gas) rich countries are at the same level as the rest of the world.

Some also argue that China's ascendance in Africa may align with the World-System Theory (WST) Predictions, which is claimed to be one of the dominant theories and frames to analyze and understand ascending economies and states around the globe (Mol 2011). The WST has emphasized on the interdependencies in the globalizing world-system and regards those ascendance as the result of "unequal exchange with and exploitation of peripheral regions and states" (Mol 2011). Mol concludes that WST only partly explains Chinese government authorities' and firms' behaviors in SSA, which are increasingly being influenced by environmental normativity, even more than the European and US TNCs did in the 19^{th} and first half of the 20^{th} centuries.

When the motive relates to renewable energy investment, new insights were brought in to the existing perspectives. The WWF report (Conrad *et al.* 2011) on China's role in enhancing Africa's energy development summarized four motives behind China's potential engagement in Africa's renewable energy sector, which are the resource motive, the entrepreneurial motive, the reputation motive and the climate motive. The resource and entrepreneurial are more realistic motives, while the reputation and climate motive, especially the latter, is more ideological.

The reputation and climate motive are somehow interlinked, as they both address the issue of turning around China's image of lacking environmental, social and labor standards in its investment activities and how China's engagement with the renewable development in Africa would create an opportunity for China to be recognized by the international community as a "responsible stakeholder" and a "contributor to international efforts of mitigating climate change". The entrepreneurial motive mentioned in is a more innovative assertion, though its essence is also about China's domestic supply and connected to the overall framework of "go out" strategy. The entrepreneurial motive sets eye on China's domestic green economy development strategy, which has led to the rise of Chinese domestic supply. Conrad *et al*. also confirmed this resource motive assertion in analyzing the motives behind China's potential engagement in Africa's renewable energy sector. The argument used to support this motive is China's financing of large hydropower projects, which is usually provided based on an infrastructure-for-resource or a resource-based loan agreement. As claimed in the report, the large hydropower projects, despite their "renewable" nature, share the same resource motive as other infrastructure projects that are following the Angola mode. In other words they are undertaken not to support Africa's energy needs but rather to secure access to its fossil resources.

Another new insight is that instead of following the traditional infrastructure-for-resource mode, the investment on renewable energy equipment manufacturing and building renewable energy generating capacity such as wind farm and solar power plants is more market-oriented, and could be tightly linked to China's domestic green economy development strategy. To some extent, expanding renewable energy equipment manufacturing in Africa is still on the path of China's "Going-out" strategy, which has been re-emphasized in the 12th Five-year Development Plan, encouraging the creation of overseas production capacity. Similar to China's domestic approach of supporting the renewable energy industry, increasing the installed renewable energy capacity would create a local demand for renewable energy equipment, thus creating a market to meet the increasing locally manufactured equipment supply.

2.3 Impact of China's outward FDI in Africa

The discussion on the impact of China's outward FDI has always been controversial. On one hand, some scholars believe that China's investment behavior is different from the traditional "Western style", considering its unique political stance, always insisting on "non-interference" to the internal affairs of the investment recipient countries as well as labeling its expansion into the African market as different from the traditional "capitalism" style. One supporting argument is that, in addition to oil field acquisition efforts, Chinese companies have also made tremendous energy and infrastructure investment in the region, supporting and sustaining local development. As Africa is recognized as a continent with abundant natural resources, yet struggling with poverty and political instability issues with electrification still one of the primary challenges impeding the economic and social development of sub-Saharan Africa, from the energy poverty perspective, proponents for China's FDI efforts in Africa consider the energy infrastructure investment as beneficial to the recipient country.

On the other, there have been critics about China's expansion, considering it as a threat to Western investors, in addition to negative social and environmental impact on the investment recipient countries. Some also doubt whether China's increasing equity oil possession would in fact enhance China's domestic energy security. A brief summary of the existing perspectives on the impact of China's FDI on Africa is also listed in Table 2.2.

In order to more comprehensive address these doubts and concerns, the following section will further illustrate some major perspectives that have appeared in the existing literature on the impact of China's FDI in Africa. The term "impact" will be explored in two dimensions, namely economic and social impact, and political impact.

Table 2. 2 Perspectives on the impact of China's FDI in Africa

Impact	Perspectives	Resources
Economic and social	Promote local employment opportunities	Tang and Gyasi 2012
		Brautigam 2009
	Positive impact on local market competency	Conrad 2012
	Positive impact on GDP	Xiao and Shen 2002
	Significant impact on GDP growth but not significant for oil rich countries	Zhang et al. 2013
	No significant impact on host country's GDP growth	Kikuchi 2013
Political	Better governance encourages FDI performance, while poor governance and infrastructure impede FDI	Dupasquier and Osakwe 2005
	Lower corruption level and less political risk would enhance FDI performance	Bhaumik and Co 2011
	May promote global energy security	Leung 2011
		Cherp and Alon 2012

Economic and social impact

As manufacturing has been a major part of China's FDI, it has been claimed that Chinese local manufacturing of inexpensive products have put local African producers under competence pressure, causing industrial restructuring and job losses. On the other hand, some studies have also pointed out that China as well as some other countries' investment have actually increased the competitiveness of the local market, thus saving the local government's cost on infrastructure projects. The World Bank report "Africa's Silk Road" also mentioned that according to field studies, interviews and surveys, local government and companies find the increasing involvement of Chinese and Indian firms a catalyst to the competitiveness and development of local market.

In the specific case of renewable equipment manufacturing, Conrad *et al.* (2011) claims that since Africa is not yet equipped with mature technology and manufacturing capability, the potential threats to existing local industry are expected to be "less of a concern". But it is also mentioned that at such an early stage, the impact of China's FDI on developing a "viable renewable energy equipment industry in Africa" is yet to be tested, but would be crucial to predicting the future trend of China's renewable engagement in Africa other than large hydropower projects. It was also implied that China's renewable infrastructure FDI and manufacturing investment would have synergic effect, in addition to enhancing China's renewable product export.

Also based on the assumption that China would further implement its going-out strategy and renewable equipment manufacturers would follow the path of auto parts and other manufacturers, the entrepreneurial motive mentioned in the previous section is expected to not only promote Chinese exports, but also enhance African local manufacturing capabilities through investment.

In terms of employment, which is also a controversial issue that has always received critics from the Africa side that Chinese companies' local investment did not create enough job local employment opportunities. According to Brautigam (2009), generally speaking, China's enterprises are employing four Africans corresponding to every Chinese employee. In another study specifically looking at the impact of China's FDI in Ghana, Tang (2012) also came up with a positive conclusion that China's FDI has led to an increase of local employment in "manufacturing, building and construction" sectors, based on the FDI and employment statistics analysis of the country.

The new insights from the perspective of renewable investment brought about by Conrad *et al*. also imply that in addition to traditionally analyzed FDI's impact on export, the expansion of renewable infrastructure investment and overseas renewable equipment manufacturing would also have synergic impacts on each other and bring out "win-win" benefit to China and Africa's economic growth and sustainable energy development.

Political impact

While China's increasing involvement in the global market only took place after the establishment of the "Go-out" strategy, Africa's FDI playground was already actively explored by Western and developed countries before the 1990s.

Due to China's "non-interference" stance to the internal affairs of the host countries, it has been labeled as different from the traditional "capitalism style" players. Such politically friendly position has been accepted and welcomed by African countries, which has also been mentioned as the major reason of China's success in the "China in Africa" story.

However, concerns have been expressed from those traditional "close partners" of Africa, assuming that China's rise in Africa would pose threat to their trade and investment activities. While this sense of "fear" is understandable in face of China's domestic development and strengthening role on the global stage in the recent decade, there is one fact that is easily neglected and blindfolded by the increase of China's OFDI in Africa: China's increasing investment in Africa only took off at the beginning of the last decade and it is still a small portion of China's total OFDI. As mentioned in the analysis of Mol, that although investment in developing countries is not a new phenomenon, China is rising at a different stage of history than when the Western explorers such as the Dutch in the 17th century, the British in the 19th century as well as the U.S. and Japan in the 20th century carried out "colonization of Southeast Asia" (Mol 2011).

On a general scale, there have been discussions about whether China's increasing possession of equity oil would improve its energy security condition. More and more recent studies (Cherp and Alon 2012; Leung 2011; Zhang 2012) have argued that this claim cannot be justified as most of China's equity oil have been sold on the global market instead of sent back to China, thus on the other hand, would actually promote global energy market mobilization and maintain the global market price stable, and may contribute to regional and global energy security.

2.4 Implication for sustainable energy development

Most of the implications proposed by scholars mentioned about collaboration, involvement and transparency. Cherp and Alon (2012) suggested that the International Energy Agency (IEA), which is a Western-oriented organization, should take a more active role to involve China in the energy sector, to guarantee more "global cooperation and equitable distribution of power". In terms of energy market, Zhang (2012) also concluded that China and other oil importing countries share profound common interest in maintaining and strengthening the stability of global oil markets and reducing the chance of potential market interruptions and price shocks, thus encouraging the Western countries to "de-politicize China's global quest for energy security" and building up mutual trust. As mentioned by Tang (2012), similar studies with more empirical data targeting specific countries, sectors and stakeholders would provide a more in-depth analysis.

While many studies have looked at China's investment in terms of bilateral relationship and investment activities between China and Africa from different perspectives, the existing literature is still dominated by infrastructure-for-resource critique, influenced by the preconceived Angola mode. However, as mentioned by Conrad *et al.* (2011), the international endeavor towards climate change mitigation is unavoidably influencing China's decision making on the global stage, and China's energy investment in Africa is one of those areas under the world spotlight, where opportunities and challenges coexist.

2.5 Conclusions

Generally speaking, there has been an increase of attention and attempts to explain China's investment in Africa, especially focusing on the motivation and impacts of China's FDI. There are competing theories from international business and politics field that have been utilized to explain China's FDI motives in Africa. There has also been an emerging trend in the literature to bring in new interpretations and adjustments to the existing theories in order to explain the China model.

In terms of the impact of China's investment, those on jobs, political situation and partially on world energy markets have been studied, but virtually no implication has been addressed on Africa's sustainable energy development.

This study would address Africa's energy needs based on sustainable energy development scenarios, and further investigate China's increasing FDI in Africa, especially focusing on energy related sectors, and profile China's role in Africa's energy development from both qualitative and quantitative aspect.

Ideally, the completed thesis would provide some implications for investors from both China and other countries, both state-owned and private, in terms of making more positive impact through energy investments that would meet the local development need in Africa. It may also provide some implications for scholars interested in making comparison studies between China and other countries in terms of energy infrastructure investment in Africa.

3. Research method

3.1 Research objectives and methods

This research is largely based on the analysis of existing literature (statistical data, scholarly studies and public documents) with some calculations performed by the author to achieve research objectives. The specific literature review focus and data collection resources are summarized in Table 3.1.

Table 3. 1 Research objectives and corresponding methods

Objectives	Literature review	Data collection
1. Understand Africa's sustainable energy target and investment needs	*Focus: Sustainable energy development target and financing*	GEA Scenario Database (IIASA)
	AfDB reports	AfDB reports
	GEA 2012	GEA 2012
	Journal articles	WEO 2011
	WEO 2011	WEC, EIA, IEA, etc (energy data)
2. Evaluate China's FDI in Africa	*Focus: Profile, motive and impact*	MOFCOM FDI database
	Journal articles	Statistical Bulletin of China's OFDI, 2006-2012
	World Bank PPI reports	UNCTAD global FDI database
3. Evaluate China's energy investment in Africa	*Focus:Infrastructure, renewable*	AidData database
	AfDB reports	CADFund and Chinese companies' report and website
	World Bank reports (AICD, etc)	International Rivers Chinese Dam in Africa database
	WWF reports (2011, 2012)	World Bank PPI database; World Bank PPI-RE specialized database
4. Compare China's investment with Africa's energy needs, evaluate China's role and potential	WWF reports	Data analysis results of part 2 and 3

3.2 Data sources and analysis

3.2.1 Data sources

One of the common limitations mentioned by previous studies on China's FDI is the lack of precise data. Such lack of data problem has also caused controversies towards to reliability of related descriptive or inferential statistical analysis. In order to fill the data gap that has been mentioned in existing literature, a comprehensive search for data from different sources has been conducted.

Based on the currently available data, some descriptive and quantitative analysis is conducted. Below is a list of the major data sources focused on FDI, which come from China, Africa and international organizations and complement each other to provide a relatively more comprehensive set of FDI related data.

Ministry of Commerce (MOFCOM)-Statistical Bulletin of China's Outward Foreign Direct Investment

The statistical bulletin presents general data on national level and broad classification of sector. A general trend of China's FDI in the past decade could be depicted, though not specifically on Africa. The proportion of China's FDI towards African countries could also be calculated.

Ministry of Commerce Public Service-Investment Project Information Database

The database was established at the end of 2012 and is still under construction and receiving project data from relevant institutions for update and adding to the historical project data.

World Bank Private Participation Infrastructure (PPI) database

The World Bank Private Participation in Infrastructure (PPI) Database provides project level data in the Africa region, which groups together the Sub-Saharan African countries. Data on infrastructure projects with private participation includes projects with at least 25% of private participation. Although the database provided quite comprehensive information for infrastructure projects in the region, smaller scale renewable energy development projects may not be captured.

The PPI data could be downloaded in the format of Excel table. Through different queries, the information on projects in different sectors, from and towards different countries and with different capacities could be filtered. Project scale, financing, capacity information could be drawn from the Excel to present an image on China's investment in Africa, in comparison with those from other countries.

The recently established World Bank PPI-Renewable Energy database, which is a specialized version of the PPI database is also a useful data source for focusing on the renewable investment field.

UNCTAD database

The United Nations Conference on Trade and Development (UNCTAD) FDI database includes inward and outward FDI flow and stock data at both country level and region level, in different measurements, such as US$ values and percentage of GDP.

AidData

AidData has been established as a partnership between the College of William and Mary, Brigham Young University, and Development Gateway to address the lack of precise data issue of China's aid and overseas FDI. The database includes 1,673 Chinese development finance projects, worthing US$75 billion in 50 African countries between 2000 and 2011.

The study of AidData was carried out in a controversial approach, namely the media-based data collection. Considering that the project level data is difficult to track from Chinese official data sources, the media-based approach, though controversial, is still providing a great amount of project information, in complementary to those provided by Chinese government or international organizations.

3.2.2 Data analysis

Some regression analyses have been conducted in previous studies about the relationship between China's FDI and the host country's political stability as well as the global economy performance. Lack and inaccuracy of data has been one major defect of these analyses, and posed controversies towards to the reliability of the result. As determinants of China's FDI in Africa is not the core objective of this study, the regression analysis approach is not adopted. Instead, the study is based on quantitative (descriptive analysis such as ratios, percentages), qualitative and case studies involving country or project level cases. The study also involves content analysis of relevant literature and reports from various sources. In-depth interview and survey is hard to be conducted at the current stage of the study, but could be more helpful for generating comprehensive qualitative analysis.

3.3 Evaluation of China's role in Africa's energy development

Previous studies have been carried out to examine the impact of FDI on recipient countries. The examined impact has been focused on economic growth, international trade and employment. In this research, the impact analysis would be focused on discovering the impact and the potential influence of China's FDI on Africa's sustainable energy development. While there is no existing theories directly addressing the impact analysis on energy development, instead of quantitative analysis such as utilizing regression models, a quantitative estimate could be made based on directly comparing between Africa's energy needs and China's FDI in the corresponding sub-sectors under the energy scope. The results from defining and quantifying the sustainable energy development needs in Africa's context are of importance to framing and scoping the evaluation.

As mentioned earlier in the literature review, some important distinctions need to be made in the discussion on China's FDI in Africa, not only in renewable energy, but also in different sectors across the continent: 1) South Africa and the rest of African countries 2) Large scale hydropower development and other energy development projects. Thus the data collection and analysis, as well case studies would address these two major distinctions and come up with results and discussions that would apply to Africa as a whole, without missing the subtle differences.

The first distinction lies in geographical distribution, between South Africa and rest of Sub-Saharan Africa. Another distinction is between large-scale hydropower and other renewable sources. Large hydro refers to hydroelectric power plants larger than 50 MW as defined by World Bank. This distinction is based on the fact that hydropower is already a commercially viable sector in Africa, while other renewable at scale is dependent on appropriate grid infrastructure and government schemes (WWF, 2012). China's involvement in renewable energy investment in Africa has mainly been focused on large hydropower development projects. According to the Foster et al. (2008), by the end of 2007, China was already providing $3.3 billion towards the construction of ten major hydropower projects amounting to some 6,000 megawatts (MW) of installed capacity. Once completed, these schemes were expected to increase the total available hydropower generation capacity in Sub-Saharan Africa by around 30%.

In addition to these two important distinctions on China's energy investment in Africa, the distinction between governmental and private investment is also important for understanding the pattern of China's FDI. As for governmental investment, it would refer to those investments made by state-owned enterprises or sponsored by public institutions, at both central and provincial level. Private investment would refer to those made by private firms that are privately owned.

In addition, it is worth noting that despite of the fact that Africa as a whole has been lagging behind the rest of the world in terms of energy development, different countries are faced with different difficulties, based on their different natural resource endowment conditions, different level of state level policy making and governance.

3.4 Limitations

Considering the major objective of this study is to examine China's role in Africa's sustainable energy development, thee demand side financing has not been emphasized.

However, there are huge hidden costs behind the inefficiencies of current power systems in Africa, which is also an important aspect of Africa's energy challenge. Although China's role in this field is limited, regional integration and trade expansion would have positive impact on Africa's energy system efficiency. One alternative way that China could assist with this is to involve energy development on the collective consultation and communication platform at China-Africa Cooperation Forum, as well as to share China's existing experience in efficiency improvement and systematic reform.

In addition, this study has mainly been based on a wide range of official and non-official data resources including World Bank PPI database, International Rivers' dam project database, AidData, MOFCOM and CADFund, as well as investor companies. Though these are also the most widely utilized data sources on China's FDI in Africa, none of them is from the African side. Ideally, the information from different aspects of the partnership could contribute to a more comprehensive comparison result, and empirical analysis could also be conducted with the availability of African countries' national level data. But realistically, to collect such level of FDI data and make further adjustments due to different recording standards would be beyond the workload of this study considering that there are 53 African countries where China's FDI are taking place.

In addition, the results in Chapter 4 shows that China's FDI is not only directed towards oil-rich countries, but also countries rich in other resources or not rich in natural resources at all. A further case study analysis on different countries with different natural resource endowment condition could make the results more illustrative, while it is also beyond the scope of this study. The WWF report (Conrad et al. 2011) has made a group of through SWOT analysis case studies to examine the challenges and risks of China's renewable energy investment in the host country, which can be referred to for future case study framework.

4. Results and discussions

This chapter will present the results of this study, which have been established based on data collection and data analysis on Africa's energy development and China's FDI, as well as review of existing literature. The chapter is structured as follows. Section 4.1 illustrates the sustainable energy development challenges in Africa. Section 4.2 depicts a profile of China's FDI, especially in Africa and energy related sectors. Section 4.3 is a further illustration of China's energy investment in Africa.

4.1 Africa's sustainable energy development challenges

Africa is home to about 15% of the world's population and 22% of its land. It also hosts an adequate share of energy reserves, but these remain largely unused. The continent has maintained an average GDP growth rate of above 4 percent in the past decade and the percentage of the population living on less than $1.25 (2005 US$) a day has dropped from 56% in 2002 to 48.5% in 2012. However, in comparison with the rest of the world, Africa still faces profound energy problems such as lack of access to modern energy, which have widespread impacts on health, gender equity, political stability, socio-economic development and the environment.

In 2010, the UN Initiative of Sustainable Energy for All put forward three major goals in terms of sustainable energy development, including providing universal access to modern energy services, doubling the share of renewable energy in the global energy mix, and doubling the global rate of improvement in energy efficiency by 2030. But what does sustainable energy mean for Africa?

Section 4.1 is structured as below to address this question. Based on the collected data from established databases of large organizations such as World Bank, OECD, UN, regional networks and national institutions as well as from existing studies, 4.1.1 will lay out Africa's sustainable energy development challenges in modern energy access, energy efficiency and energy security based on the current status of the energy resource, supply and demand condition, while 4.1.2 illustrates the current energy development financing status in Africa. In 4.1.3, several projections, including the Global Energy Assessment (GEA) scenarios, the World Energy Outlook (WEO) scenario and the African Energy Outlook scenario, are interpreted in Africa's context and compared with the current status. The technical and financial gaps, which arise from the comparison, are summarized in 4.1.4.

4.1.1 Current energy status

4.1.1.1Energy resources and primary energy supply

Africa is a continent endowed with considerable and untapped energy resources, including crude oil, natural gas, coal, hydro, geothermal, biomass, solar and wind. At the end of 2008, the continent had over 17 billion tonnes (137 billion barrels) of proven crude oil reserves and over 14.6 trillion cubic meters of proven natural gas reserves, which is about 11% of the world's proven oil reserves and 10% of the world's natural gas reserves (WEC, 2010; UNIDO, 2009). The share of oil and gas is expected to further increase, especially with the recent yet unspecified discovery of reserves in the Great Rift Valley of East Africa.

Africa is also contributing to energy resources export, though most countries, especially those in sub-Saharan Africa are net oil importers. According to the 2012 energy policy report of African Development Bank Group (AfDB), Africa holds 12.1 percent of the world's crude oil production, 6.8 percent of the natural gas output, 4.2 percent of hard coal and 4.6 percent of global hydro-electric power and is exporting 475 million tonnes of oil equivalent per year, which accounts for 40-45% of the continent's production (AfDB, 2008; 2012). On the other hand, the continent, home to 15% of the world's population, only consumes 3.5% of the energy consumed globally. One major cause to the contrasts and many of Africa's energy problems is the uneven distribution of the energy resources in combination with lack of interstate energy trade on the continent (UNIDO, 2009).

In terms of oil and gas, the continent only consumes 9% of its total oil production and the rest is for export (AfDB, 2008). The top four exporters with net exports exceeding 1 million barrels per day include Nigeria, Angola, Algeria and Libya. As shown in Fig. 4.1, these four countries together hold almost 90% of the continent's oil reserves and more than 80% of the continent's crude oil production, and two of them are in North Africa. Sudan (before 2011) used to be among the top oil producers, but the cease of oil production in South Sudan after its independence in 2011 led to an immediate drop of the total oil production of the two countries (shown as Sudan in the figure, currently Sudan and South Sudan). The natural gas reserves and production shares the same pattern as crude oil, with the four countries, namely Nigeria, Algeria, Egypt and Libya dominating the ownership.

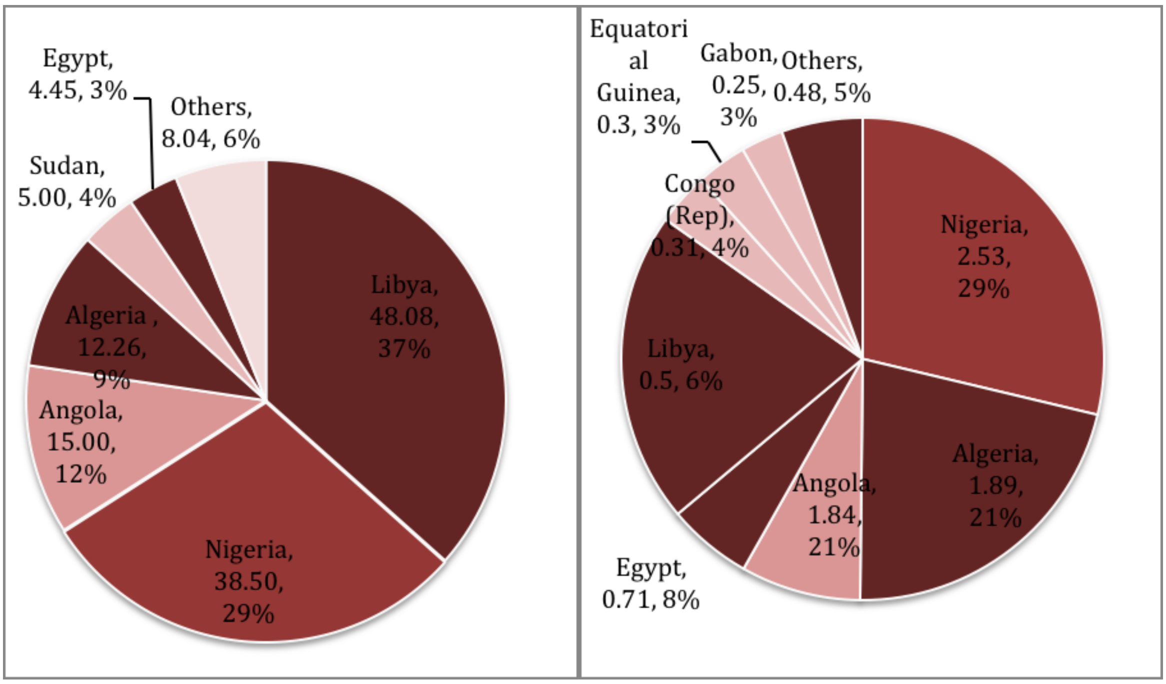


Fig. 4. 1 Proved oil reserve and crude oil production distribution in Africa, 2011
Data source: CIA World Factbook
Note: Color of the components also implies the region in Africa that the country belongs to (e.g. Northern Africa, Western Africa, etc)

In terms of coal, Africa is home to only no more than 4% of the world's total proved coal reserves and production. More than 95% of the proven coal reserves and 98% of the coal production in Africa are located in South Africa, where coal export accounts for 27% of its total export output (WEC 2010).

Table 4. 1 Africa and world proved recoverable coal reserves and production, 2008

	Proved reserves (Billion tonnes)	**2008 Production (Million tonnes)**
World total	860.938	6739.2
Africa	31.692	255.4
Africa's share in the world	3.68%	3.79%
South Africa	30.156	251
Zimbabwe	0.502	2.7
Botswana	0.040	0.9
Niger	0.070	0.2
Swaziland	0.144	0.2
Zambia	0.010	0.2
DR Congo	0.003	0.1
Malawi	0.002	0.1

Data source: WEC 2010

Renewable energy potential in Africa is also attractive yet unevenly distributed. It is estimated that Africa has 1,750 terawatt-hour (TWh) potential of hydropower, only 5% of which has been exploited and half of which is estimated to be in DR Congo. Some other countries with hydropower potentials include Ethiopia, Cameroon, Angola, Madagascar, Gabon, Mozambique and Nigeria (Eberhard *et al*. 2011). The same figure for geothermal is 14,000 MW and 0.5% (UNIDO 2009) and the only countries that have started to put geothermal into commercial use are Kenya and Ethiopia, while the resource is abundant across the continent, especially at the Great Rift Valley region. Solar energy is large across the continent as it receives abundant solar radiation throughout the year.

Other renewable energy potentials are also promising, such as the favorable wind resources in North Africa, the Horn of Africa, South Africa and some other inland areas, and biomass, which is expected to play a bigger role in some areas such as East Africa (UNIDO 2009;

WEO 2011). It was even estimated that a significant portion of the electricity needs in both Eastern and Southern Africa could be met by bagasse-based cogeneration in the sugar industry.

Traditional biomass, despite of its harm on health and environment, remains the main source of energy supply in sub-Saharan Africa, even in some oil-rich countries such as Nigeria. In some countries in sub-Saharan Africa, biomass energy contributes to more than 90% of total energy supply.

Africa is also home to 16.1% of the total proved uranium reserves in the world (WEC, 2010), but only one nuclear power plant has been built on the continent so far, which is the 1800 MW Koeberg station in South Africa (Eberhard *et al*. 2011) The uranium potential mainly exists in Niger , South Africa and Namibia (WEC, 2010; Eberhard *et al*. 2011).

Generally speaking, Africa has adequate but unevenly distributed energy potentials, in terms of both non-renewable and renewable. While fossil fuels are concentrated in Northern Africa and only a few countries in sub-Saharan Africa, sub-Saharan African countries have huge potential in renewable resources and some countries in Great Rift Valley also have potential reserves to be proved. The "realistic potential" of Africa is yet to be realized through both technical and financial supports, so that the resources could be more effectively utilized and distributed across the continent and benefit the currently energy-deprived African population, especially in sub-Saharan Africa.

4.1.1.2 Energy consumption and supply

Energy consumption

The total primary energy consumption in Africa has been growing steadily yet slowly in the past three decades as shown in Fig. 4.2. In face of the faster growing population on the continent, the per capita consumption level in Africa made very little change in the past three decades, from 14.29 million Btu per capita in 1980 to 15.93 million Btu per capita in 2010. The gap between Africa's per capita consumption level and the world per capita consumption level is still huge and even increased, considering that Africa's consumption level has been lagging behind most parts of the world, where per capita consumption level has been increasing along with socio-economic development.

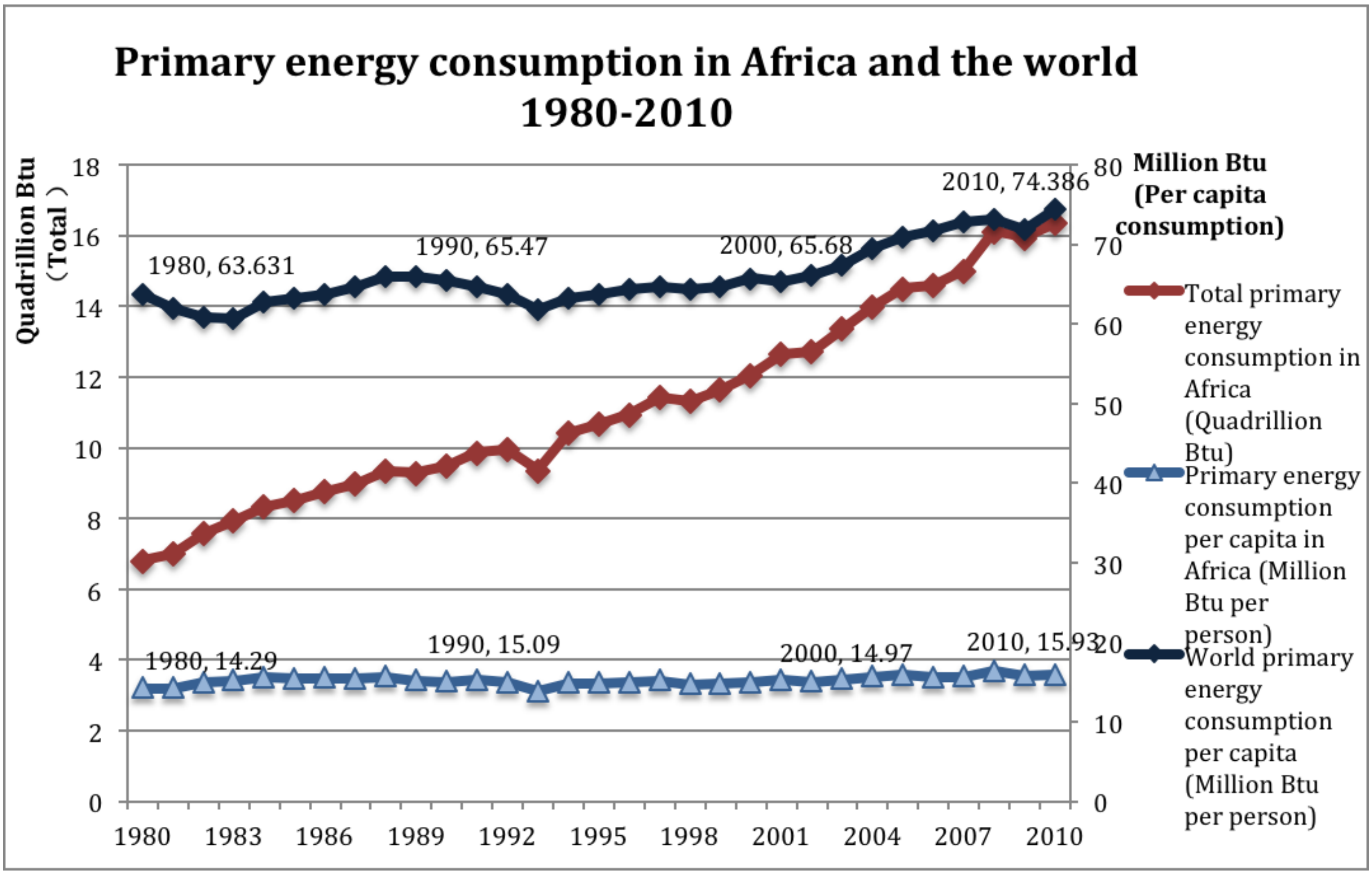


Fig. 4. 2 Primary energy consumption in Africa (Total and per capita), 1980-2010
Data source: EIA, International Energy Statistics and calculations

Electricity generation

In terms of electricity generation capacity, the total installed capacity has been growing steadily, though the growth has not been minimal in face of Africa's growing population and urbanization. Although the total installed capacity reached 133.8 GW for the whole continent, about one third of that is from South Africa and another 40% is from Northern Africa, leaving the rest of sub-Saharan Africa with no more than 40 GW installed capacity. Fossil fuels are the majority of the installed capacity source, and the share of fossil fuels in total capacity remains stable at around 78%. Hydropower is the second largest source of electricity generation following coal. However, the installed capacity grew by only no more than 4 GW in the past decade and its share even decreased by 1%. The non-hydro renewable electricity generation capacity has grown from 0.43 GW to 1.68 GW, and its share in the total capacity has increased from 0.4% to 1.25%. Table 4.2 and Fig. 4.3 demonstrate a further breakdown of different components of the electricity generation installed capacity in Africa.

Table 4. 2 Electricity installed capacity in Africa by type (GW), 2010

Year	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
Total electricity capacity	105.34	106.73	107.24	111.34	113.86	117.17	119.05	123.73	130.05	133.78
Fossil fuels total (conventional thermal)	80.75	81.76	82.26	85.48	87.69	91.25	92.78	96.91	101.76	104.38
Renewable total	21.39	21.78	21.78	22.20	22.51	22.26	22.61	23.16	24.63	25.73
Hydro	20.95	21.31	21.24	21.56	21.62	21.30	21.49	21.90	23.12	24.06
Non-hydro renewable	0.44	0.46	0.54	0.64	0.89	0.96	1.12	1.26	1.51	1.68
Geothermal					0.12	0.12	0.12	0.12	0.18	0.18
Solar					0.01	0.01	0.01	0.02	0.02	0.02
Wind					0.23	0.29	0.45	0.57	0.76	0.93
Biomass and waste					0.54	0.54	0.54	0.55	0.55	0.55
Hydroelectric Pumped Storage	1.40	1.40	1.40	1.86	1.86	1.86	1.86	1.86	1.86	1.86
Nuclear	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8

Data source: U.S. Energy Information Administration (EIA)

Currently, coal is the single largest source of electricity generation in Africa accounting for more than 55% of the total production, as illustrated in Table 4.3. The shares of the major renewable sources of electricity production are also listed in Table 4.4. But as projected in the trade expansion scenario (AICD 2009) which will be further explained in 4.1.3 future energy scenario descriptions, hydro is expected to take over the place and oil and gas are also expected to rise, as shown in Fig. 4.4.

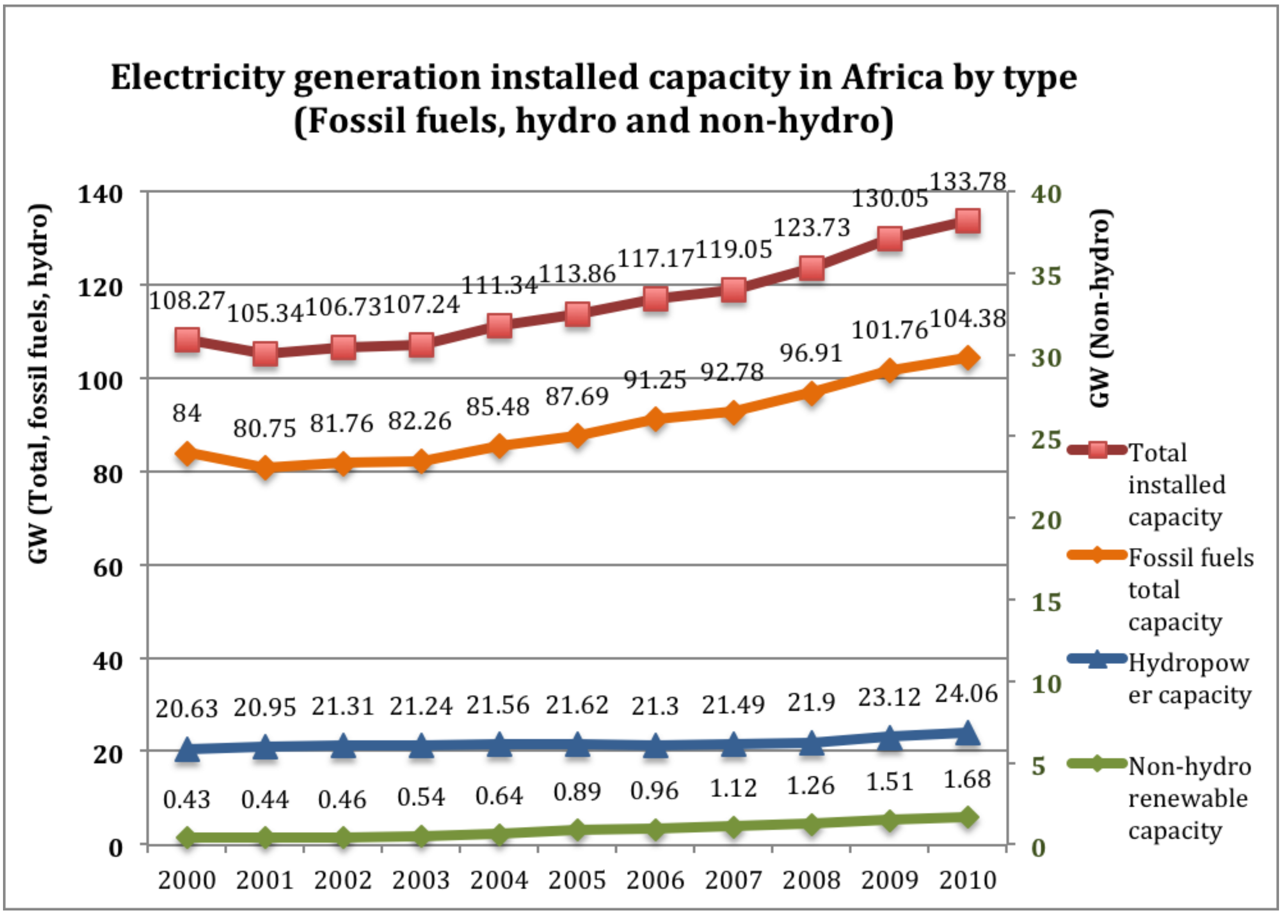


Fig. 4. 3 Electricity generation installed capacity in Africa by type
Data source: EIA International Energy Statistics

Table 4. 3 Electricity generation by source and region, 2010

Source	**Electricity production (Billion kWh)**	**Coal (% of total)**	**Natural gas (% of total)**	**Oil (% of total)**	**Hydroelectric (% of total)**	**Nuclear (% of total)**
World	**21448.9**	**40.5**	**22.2**	**4.3**	**15.9**	**12.9**
Sub-Saharan Africa	**441.4**	**55.8**	**5.4**	**10.5**	**18.6**	**2.7**
East Asia & Pacific	4,888.80	71	7.4	1.3	16.5	1.5
Europe & Central Asia	1,884.30	23.8	40.8	0.9	18.8	15.3
Latin America & Caribbean	1,356.40	5.3	22.9	10.8	53.7	2
Middle East & North Africa	638.4	1.8	65.7	25.4	5.4	0
South Asia	1,120.10	58.4	16.2	6	14	2.7

Data source: World Bank

It is worth to note that the renewable electricity generation has been increasing both in terms of installed capacity and total renewable electricity generation as shown in Table 4.4. The non-hydro renewable electricity generation is more than doubled from 2000 to 2010, though it still accounts for hardly 1% of the total electricity generated on the continent. Table 4.5 presents the major African countries in terms of renewable electricity generation capacity by type. It can be seen that the limited renewable electricity installed capacity has been distributed across the continent, which somehow corresponds with the diversified and unevenly distributed renewable energy resource situation in Africa.

Table 4. 4 Electricity generation in Africa by type (Billion kWh), 2000-2010

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Total electricity generation	419.5	436.5	461.5	483.5	513.7	533.6	555.9	580.4	586.3	594.1	631.5
Renewable total	77.0	84.0	86.1	84.9	90.3	93.0	95.0	96.8	97.6	102.1	110.9
Hydroelectricity	74.5	81.2	83.4	81.7	86.5	89.3	90.5	92.5	92.9	96.8	104.8
Non-hydro renewable	2.5	2.8	2.7	3.2	3.8	3.8	4.5	4.3	4.7	5.3	6.1
Solar, tide and wave	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Geothermal	0.4	0.5	0.4	0.8	1.0	1.0	1.0	1.0	1.2	1.4	1.5
Biomass and waste	1.8	1.9	1.8	1.8	1.9	1.9	2.6	2.1	2.2	2.2	2.3
Wind	0.2	0.5	0.5	0.6	0.8	0.8	0.9	1.2	1.3	1.7	2.4

Data source: EIA International Energy Statistic

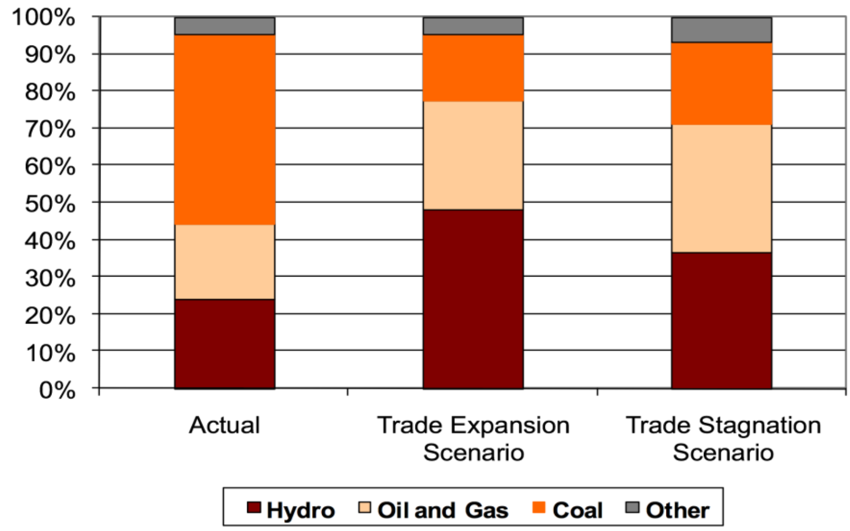


Fig. 4. 4 Share of primary energy sources in electricity production in Africa
Source: AICD, 2009

Table 4. 5 Installed renewable energy capacity in Africa, 2008

	Hydropower (GW)		Solar (MWp)		Wind (MW)		Geothermal		
							Electricity (MWe)		Direct use (MWt)
World	1170 GW		17.4 GW		17.4 GW		14.9 GW		-
Africa	17.5 GW		33.9 MW		523 MW		172 MW		130
Share of Africa	2%		0.2%		0.5%		1.6%		-
Countries with top capacity	DR Congo	2.41	South Africa	12	Egypt	365	Kenya	163	16
	Mozambique	2.18	Morocco	10	Morocco	114	Ethiopia	9	2
	Nigeria	1.9	Egypt	4.5	Tunisia	19	Algeria	-	56
	Zambia	1.63	Ethiopia	2.9	South Africa	9	Tunisia	-	44
	Ghana	1.18	Algeria	2.8	Cape Verde Islands	3	South Africa	-	6
	Angola	0.79	Tanzania	1.2	Réunion	10			

Data source: EIA International Energy Statistcs, WEO 2010 and own calculations

4.1.1.3 Energy challenges

The African continent, especially sub-Saharan Africa, is faced with some crucial energy challenges including high dependence on traditional biomass and electricity supply shortfalls in face of population growth and urbanization, as well as low level of energy efficiency which results in higher financial cost. In order to link with the focus of this study, which is on China's role in energy investments in Africa and the sustainable energy development of the continent, this section would address the energy challenges of Africa in three aspects: modern energy access, energy security and financing.

Modern energy access

The primary energy challenge faced by Africa lies in the access to modern energy, mainly represented by access to electricity and clean cooking facilities. In some countries in sub-Saharan Africa, biomass accounts for as high as 90% of household energy needs, mostly for cooking purposes. The energy access challenge is especially prevalent in the rural areas of Sub-Saharan Africa, where 585 million people have no access to electricity and traditional biomass remains the major source of energy supply, especially for cooking purposes. As shown in Table 4.6 Africa has the lowest electrification rate in comparison to any other developing region and more than one third of the world's population without access to electricity live in sub-Saharan Africa. In the rural areas in sub-Saharan Africa, the case is the worst, where the electrification rate is as low as 14.2%. However, in contrast with sub-Saharan Africa, almost all the countries in North Africa, which is also home to the major oil producers of the continent, have achieved universal access to electricity, except Mauritania.

Table 4. 6 Electrification rate in rural and urban areas by region, 2009

	Population without electricity (million)	Electrification rate (%)	Urban electrification rate (%)	Rural electrification rate (%)
World total	1,317	80.5	93.7	68.0
Developing countries	1,314	74.7	90.6	63.2
Africa	587	41.8	68.8	25.0
North Africa	2	99.0	99.6	98.4
Sub-Saharan Africa	585	30.5	59.9	14.2
Developing Asia	675	81.0	94.0	73.2
China & East Asia	182	90.8	96.4	86.4
South Asia	493	68.5	89.5	59.9
Latin America	31	93.2	98.8	73.6
Middle East	21	89.0	98.5	71.8

Source: IEA 2010

It has been projected that according to the current population growth rate and the energy development baseline scenarios, by 2030, the African population without access to modern energy will be even higher and 654 million people may be added to the population without access to electricity, which is 587 million at the 2009 baseline level (GEA 2012).

The dominant reliance on traditional biomass and lack of access to electricity is not only impeding local economic development, but also leading to serious health and environmental damage. Indoor air pollution fro solid biomass burning is responsible for diseases that cause more deaths globally than malaria and tuberculosis (IEA and WHO 2010). It has also been estimated that more than one third of the deaths caused by IAPs worldwide occur in sub-

Saharan Africa (UNDP 2009). It has also been addressed that women and children are the most vulnerable groups under the negative impact of insufficient access to modern energy.

According to World Bank estimation, sub-Saharan Africa needs an additional capacity of 4 GW per year in order to power its economic growth and keep up with the demand for electricity, which is growing at about 5 percent per year in many countries in the region, in contrast with the fact that only 1 GW is being added annually. While sub-Saharan Africa in general is faced with severe energy access challenges, the situations in different regions and countries also differ, considering the uneven distribution of the continent's energy supply.

Energy security

The current structure of Africa's energy supply and electricity generation poses huge risks to the continent's energy security considering the fact that most of the countries in sub-Saharan Africa are non oil-producing countries and rely on oil import. Although currently Africa's fossil fuels use is still in small quantity, in order to sustain its growing population and urbanization and maintain its economic growth, the continent's energy demand is expected to increase steadily, and faster than the previous decades.

From a long-term perspective, renewable energy would add to the flexibility and resilience of the energy supply system in Africa. In addition, it is estimated that only 5% of the continent's potential of hydropower has been exploited and the same figure for geothermal is 0.6%. In order to achieve a more secure energy future instead of following the traditional path over-relying on fossil fuels, tackling the abundant yet largely underutilized renewable energy to fuel the continent's development is a promising yet challenging task requiring both technical and financial dedications.

The opportunities lie in the promotion and application of modern biomass technologies and the use of renewable energy resources. Recent oil and gas findings are also posing a new development opportunity for the region, which could potentially boost the modern energy supply.

While the African continent in general is receiving high expectations on its modern energy development, the leapfrogging is difficult to realize without sufficient and reliable financing and technology supports. In addition, the energy related challenges that are currently faced by Africa are not only causing social and economic damage as well as political instability to the African community, but may also have a regional and global impact thus as global energy security and climate change.

Energy financing

Lack of financial and technical support are the two major barriers to Africa's renewable energy development. Lack of access to capital exists at every scale, from households, the majority of which depends on less than US$2 per day, to large utilities, as well as to governments (GEA 2012). While the global investment in renewable energy has increased more than ten times in the past decade, Africa only witnessed a very limited percentage of the investment. Among the $100 billion global investment in the renewable energy capacity, manufacturing and research and development, only $1 billion was received by Africa (excluding large hydro).

The energy financing system has been transforming in the past two decades worldwide. The components of energy financing on a global level is shown in Fig. 4.5. Until the 1990s, most developing countries, including African countries, have been relying on international financial institutions such as the World Bank and regional development banks for investment in the energy sector.

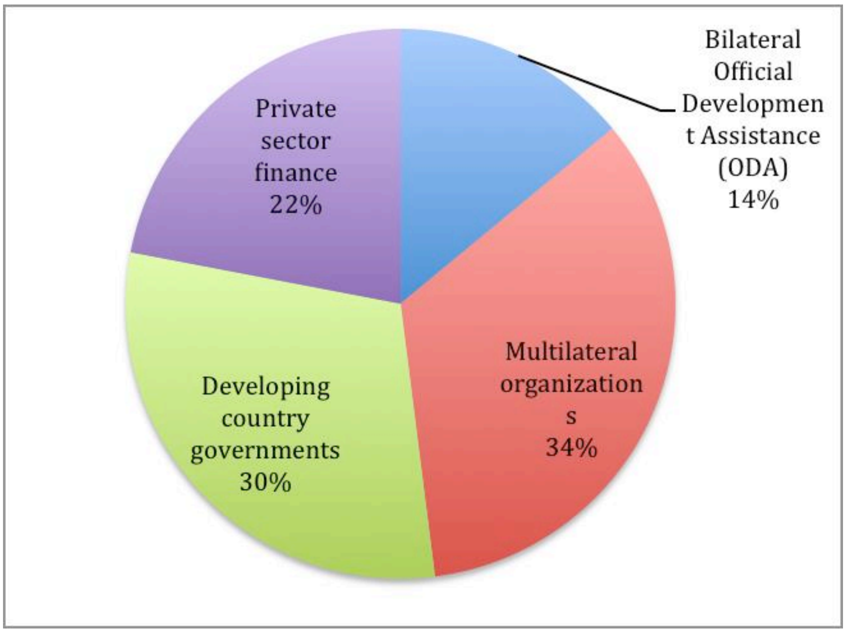


Fig. 4. 5 Share of total investment in energy access by source, 2009 (Total investment=$9.1 billion)
Data source: World Bank PPI

The contribution of official development assistance (ODA) to public investment in the power sector has also been volatile and modest, averaging only $0.7 billion per year in the last decade. According to OECD data (2006), the total external capital flows to the power sector in Sub-Saharan Africa, including ODA and PPI, account to no more than 0.1 percent of the region's GDP, while the countries in Sub-Saharan Africa, on average spend 2.7 percent of their GP on the power sector.

In the 1980s, the World Bank started to promote private investment, which led to more active involvement of private investors. However, the performance and contribution of private sector financing has been neither stable, nor substantial. As for Africa, private sector financing accounted for an average of $0.3 billion over the past decade between 2000 and 2010, against a total investment need of $ 4 billion per year. According to the World Bank PPI report (2012), the number of private investment on infrastructure projects has been declining in Africa in recent few years, but the private investment in the energy sector has been on a rise as shown in Fig. 4.6. In 2011, the total investment in energy sector with private participation reaches US$1.35 billion (US$0.794 billion on 9 new projects and the rest for additional investment in previously implemented 4 projects), which is the highest since 2007 (World Bank PPI 2012). Of the 13 projects, only 2 had domestic investors involved and Chinese company Shenzhen Electric is among the top 10 sponsors.

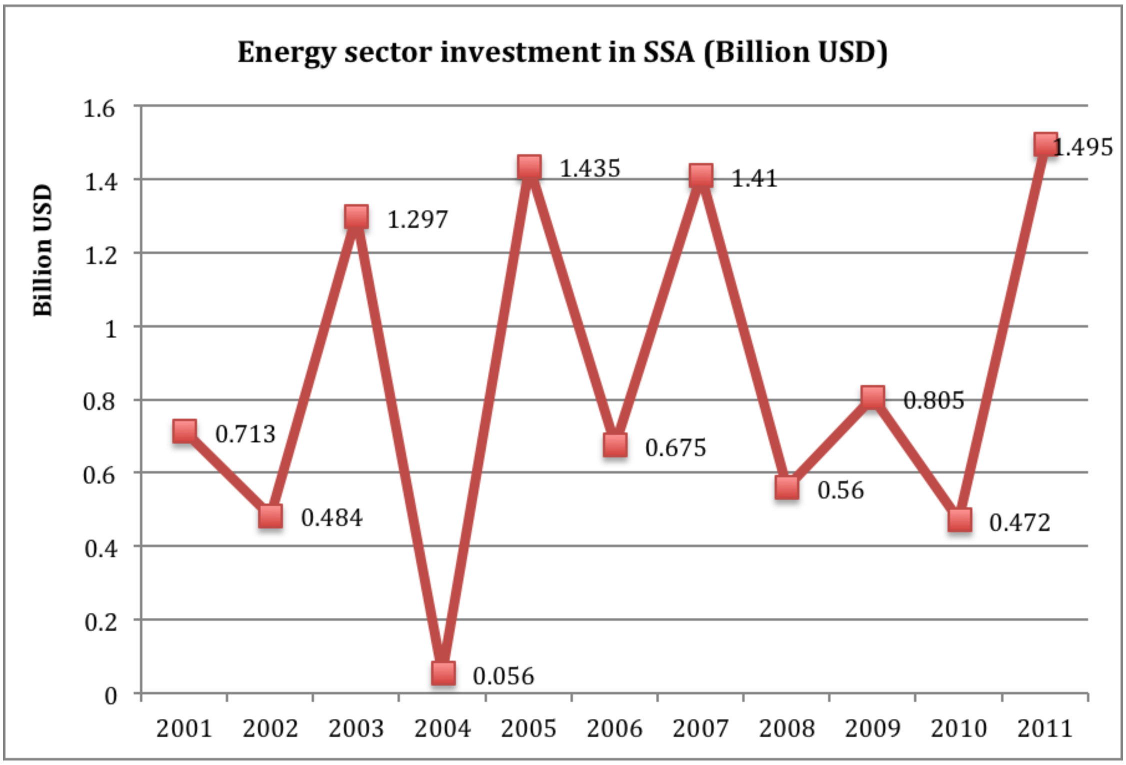


Fig. 4. 6 Energy sector investment in sub-Saharan Africa (Billion USD), 2001-2011
Data source: World Bank PPI

Generally speaking, Africa lacks domestic capacity in energy financing and has a high demand for energy investment from the rest of the world. A more quantitative description of Africa's financing gap between the business-as-usual scenario and the sustainable energy development scenario will be presented in section 4.1.3 based on the projections under different scenarios.

4.1.2 Sustainable energy scenarios

This section is focused on presenting the major scenarios that have been proposed by GEA, WEO as well as African institutions and quantifying the energy needs that are expected to be met under a realistic expectation, while the next section 4.1.3 would depict the financing gap based on these scenarios.

4.1.2.1 Global Energy Assessment (GEA) scenarios (IIASA 2012)

The Global Energy Assessment report illustrates the energy challenges and presents the future scenarios in a holistic approach, making the huge energy challenges easier to decompose and the energy future more visible and viable.

GEA explored 60 alternative pathways of energy transformations towards sustainable energy development, presenting a broad range of choices and diversified potentials for the world's future energy development. In addition to the high level of diversity, what distinguishes the GEA scenario design from some other projection designs is its goal setting, which addresses not only energy challenges, but also environmental and social issues that are linked to the energy challenges.

The four principle energy goals are improving energy access, reducing air pollution to improve human health, avoiding dangerous climate change, and improving energy security (Riahi et al. 2012). Among the 60 pathways, it is claimed in GEA report that 40 meet all of the GEA goals simultaneously. In addition, the GEA also adopted adequate energy services to support economic growth as a normative goal (Riahi et al. 2012). To some extent, the GEA pathways represent the most comprehensive interpretation of the sustainable-energy-for-all ideology.

The pathways are divided into three groups, namely GEA-Supply, GEA-Mix and GEA-Efficiency (Johansson *et al*. 2012). The three groups share common socio-economic assumptions such as population and GDP growth pattern, which are shown in Fig. 4.7. But as the names imply, have different emphasis and lead to rather different future scenarios.

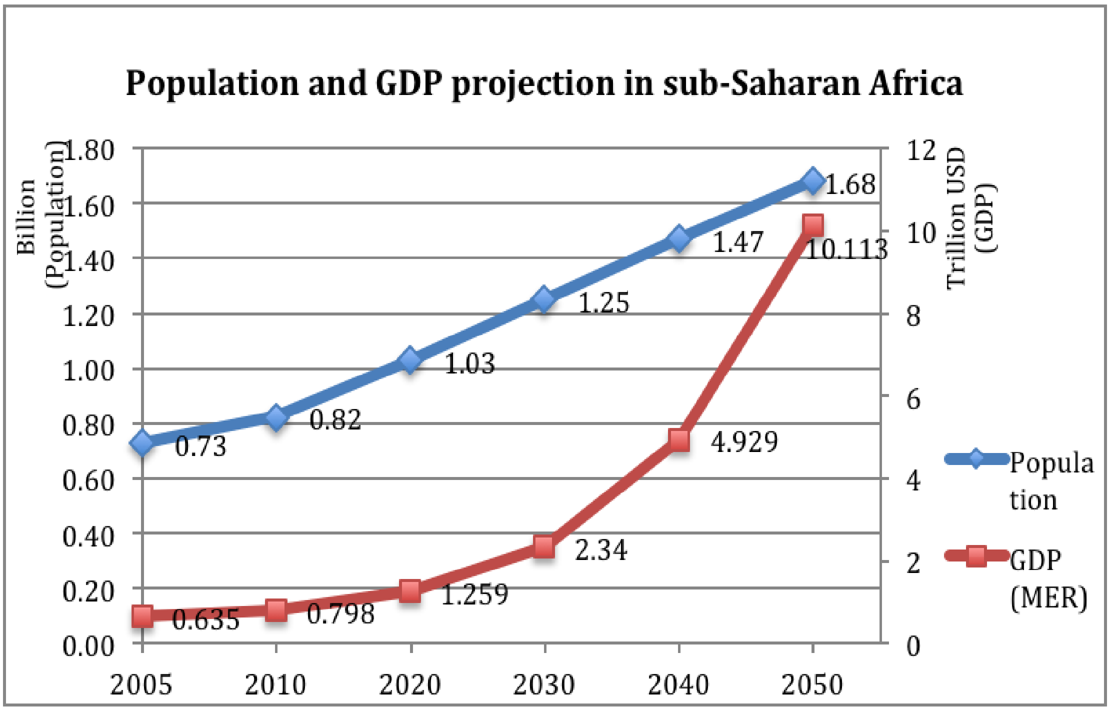


Fig. 4. 7 Population and GDP projection in sub-Saharan Africa under GEA Scenarios
Data source: GEA Scenario database

The GEA-Supply group focuses on radical supply-side transformation based on adoption of new infrastructures, fuels and technologies such as hydrogen, electric vehicles and CCS, but the energy mix transformation would take place along with fast energy demand growth. The GEA-Efficiency group focuses on demand-side improvement of efficiency, which leads to significant energy demand decrease, represented by rapid energy intensity improvement and increasing reliance on renewable energy. The GEA-Mix group is in between the GEA-Supply and GEA-Efficiency group, with no extreme focus on either demand side or supply side, but characterized by the diversity of energy supply and high resilience towards technology shocks. The GEA-Mix group also allows different regions more flexibility to adopt the portfolios taking local resource advantage and restrictions into consideration, which is the major reason that the GEA-Mix scenario was chosen to demonstrate the 2010-2030 sustainable energy development scenario of Africa.

On the next level, among each of the three groups, the pathways could be further divided based on the dominant transportation fuels and technologies, namely conventional and advanced transportation, where the advanced transportation is characterized by the increasing adoption of electric and hydrogen fueled vehicles. Under each transportation scenario, pathways could be further divided into Full portfolio pathways and Restricted portfolios, the latter of which excludes or limits certain supply-side options such as the share of renewable energy options in the portfolio. However, even under certain constraints, some mature renewable technologies such as hydropower and wind power are still showing dramatic increase in the portfolio.

Since this study is focused on Africa, especially sub-Saharan Africa, which is home to adequate untapped renewable and non-renewable energy resources and lack of technology and financing to bring in energy transformation, there are huge potentials to discover from both demand and supply side. In such case, the Illustrative GEA-Mix scenario is chosen among the diversified scenarios in the GEA Scenario database to present a more balanced yet resilient projection for Africa's sustainable energy development. The MESSAGE-Baseline scenario is chosen as business-as-usual or baseline, for comparison purpose.

Some of the GEA-Mix scenario's projected indicators of sub-Saharan Africa reflecting energy access situation are presented in Table 4.7, 4.8 and 4.9 as below. Table 4.8 includes a list of the electricity access indicators and the comparison with the rest of the world. A clear contrast can be seen between North Africa, where almost universal electricity has been achieved and sub-Saharan Africa, where the rural electrification rate is even below 15%. In addition, Table 4.10 summarizes the electricity mix components as a result of the two different scenarios designs. It is worth noting that renewable energy is playing a much more important role in GEA-Mix scenario between 2010 and 2030, and is expected to account for more than half of electricity generation sources in Africa by 2030. A further discussion will be presented in section 4.3.

Table 4. 7 GEA-Mix Scenario modern energy access indicators- electricity access

	Population without electricity (million)	**Electrification rate (%)**	**Urban electrification rate (%)**	**Rural electrification rate (%)**
World total	1,317	80.5	93.7	68.0
Developing countries	1,314	74.7	90.6	63.2
Africa	587	41.8	68.8	25.0
North Africa	2	99.0	99.6	98.4
Sub-Saharan Africa	585	30.5	59.9	14.2
Developing Asia	675	81.0	94.0	73.2
China & East Asia	182	90.8	96.4	86.4
South Asia	493	68.5	89.5	59.9
Latin America	31	93.2	98.8	73.6
Middle East	21	89.0	98.5	71.8

Data source : GEA Scenario database

Table 4. 8 GEA Scenario modern energy access indicators-biomass in final energy use (EJ/yr)

Year		2005	2010	2020	2030	2040	2050
Biomass total	Baseline	5.25	6.02	4.19	4.83	8.66	11.81
	GEA-Mix			6.17	8.92	11.06	9.33
Traditional biomass	Baseline	4.31	4.78	2.21	2.07	1.92	0.00
	GEA-Mix			2.21	2.06	1.92	0.00
Residential and commercial	Baseline	4.31	4.81	2.48	3.47	4.51	0.76
	GEA-Mix			2.48	3.41	3.32	0.11
Industry	Baseline	0.94	1.21	1.71	1.36	4.15	11.05
	GEA-Mix			3.69	5.50	7.73	9.22

Data source: GEA Scenario database

Table 4. 9 GEA Scenario energy diversity indicators-electricity generation mix component (Billion kWh/yr)

Year				2005	2010	2020	2030	2040	2050
Fossil fuel	Coal	Baseline		236.86	314.97	597.42	898.22	1663.27	2501.17
		GEA-Mix total				173.07	88.08	41.23	17.94
		GEA-Mix	w/o CCS	236.86	314.97	173.07	88.08	38.95	10.72
			w/CCS	0.00	0.00	0.00	0.00	2.29	7.22
	Gas	Baseline		17.24	35.03	139.28	269.10	394.20	675.82
		GEA-Mix	w/o CCS			361.88	390.24	308.56	122.07
			w/CCS	0.00	0.00	0.00	133.46	414.89	1021.93
	Oil	Baseline		16.40	11.95	7.23	4.17	1.39	0.56
		GEA-Mix				8.55	4.15	1.41	0.49
	Fossil fuel total	Baseline		507.35	676.93	743.93	1171.49	2058.87	3177.54
		GEA-Mix				543.50	615.92	766.10	1162.43
Renewable	Biomass	Baseline		0.00	0.00	0.00	0.00	0.00	60.05
		GEA-Mix total				69.24	171.35	178.03	151.92
		GEA-Mix	w/o CCS	0.00	0.00	69.24	170.46	175.21	144.94
			w/CCS	0.00	0.00	0.00	0.89	2.82	6.98
	Geothermal	Baseline		0.83	1.39	1.39	1.11	0.28	0.00
		GEA-Mix				1.39	1.13	24.34	24.22
	Hydro	Baseline		75.34	83.96	122.88	163.19	197.94	223.79
		GEA-Mix				148.80	227.83	429.73	534.86
	Solar Total	Baseline		0.00	1.39	82.57	309.69	783.96	1655.49
		GEA-Mix				37.65	128.01	306.63	590.76
	Solar CSP	Baseline		0.00	0.00	71.72	260.49	603.82	1163.15
		GEA-Mix				71.80	260.54	603.87	1163.13
	Solar PV	Baseline		0.00	1.39	10.84	49.21	180.14	492.62
		GEA-Mix				37.65	128.01	306.63	590.76
	Wind	Baseline		0.00	1.67	1.67	1.67	0.83	242.69
		GEA-Mix				46.04	106.75	388.64	1071.55
	Renewable total	Baseline		76.17	88.40	208.50	475.66	983.01	2182.02
		GEA-Mix				303.12	635.07	1327.36	2373.29
Other	Nuclear	Baseline		0.04	0.04	0.02	0.00	0.00	0.00
		GEA-Mix				0.02	0.31	0.97	2.34
Total						952.44	1647.15	3041.88	5359.56
				583.57	765.37	846.63	1251.31	2094.44	3538.06

Data source: GEA Scenario database and own calculations

Note: w/CCS and w/o CCS respectively refer to adopting or not adopting CCS technology

4.1.2.2 Modern energy access scenarios (WEO 2011)

According to World Energy Outlook (2011) definition, modern energy access is "a household having reliable and affordable access to clean cooking facilities, a first connection to electricity and then an increasing level of electricity consumption over time to reach the regional coverage", on the assumption of five people per household.

In the definition, reliable access to clean cooking facilities refers to the provision of cooking facilities which can be used without or with less harm to the heath, more environmentally sustainable and energy-efficient in comparison with the average biomass cookstoves that are being widely used in developing countries. In particular, the clean cooking facilities include biogas systems, liquefied petroleum gas (LPG) stoves and improved biomass cookstoves with lower emissions and higher efficiencies than the traditional three-stone stoves.

Scenario 1: New Policies Scenario (2010-2030)

The initial threshold level of electricity consumption is assumed to be 250 kilowatt-hours (kWh) per year for rural households and 500kWh per year for urban households (WEO 2011), to meet their respective levels of basic livelihood requirements for electricity. After the initial electricity access, it is further assumed that the consumption level would rise and as defined, "reach the regional average" after five years. In 2030, the average electricity annual consumption level is expected to be 800 kWh per capita. The New Policies Scenario is expected to enable 550 additional million people with access to electricity and 860 million people provided with clean cooking facilities during the period.

Under the New Policies Scenario, while both the population and the percentage share of population without access to electricity on the global level and most developing countries are expected to decrease from 2009 to 2030, Sub-Saharan Africa is the only region that is expected to have an increasing population without access to electricity as shown in Table

4.10. In the rural area, the case is even worse. The major cause is the rate of population growth that will exceed the rate of connections. In contrast, China is expected to achieve 100% electrification by 2015.

Similar trend appears in the access to clean facilities projection as shown in Table 4.11. While the global population without access to clean cooking facilities remain at 2.7 billion level, the proportion of population drops from 39% in 2009 to 33% in 2030. Against the global trend, the population in the SSA region without clean cooking facilities is expected to reach 900 million, accounting for one third of the global population without access to clean cooking facilities.

Table 4. 10 WEO New Policies Scenario modern energy access indicators-population without access to electricity (million)

Year	2009				2030			
Region	**Rural**	**Urban**	**Total**	**SoP**	**Rural**	**Urban**	**Total**	**SoP**
Africa	466	121	587	58%	539	107	646	42%
SSA	465	121	586	69%	538	107	645	49%
World	1109	208	1317	19%	879	157	1036	12%
Share of SSA	42%	58%	44%	-	61%	68%	62%	-
China	8	0	8	1%	0	0	0	0%

Data source: WEO 2011 and calculations

Note: SoP stands for share of population

Table 4. 11 WEO New Policies Scenario modern energy access indicators-population without access to clean cooking facilities (million)

	2009				2030			
Region	**Rural**	**Urban**	**Total**	**SoP**	**Rural**	**Urban**	**Total**	**SoP**
Africa	480	177	657	65%	641	270	911	58%
SSA	476	177	653	78%	638	270	908	67%
World	2221	441	2662	39%	2230	485	2715	33%
Share of SSA	21%	40%	25%	-	29%	56%	33%	-
China	377	46	423	32%	236	25	261	19%

Data source: WEO 2011 and calculations

Scenario 2: Modern Energy Access for all Scenario (2010-2030)

The Modern Energy Access for all Scenario, as the name implies, refers to the universal access to electricity and clean cooking facilities by 2030.

As for the sub-goal of universal access to electricity, it requires a total incremental electricity output of around 840 terawatt-hours (TWh) and additional power generating capacity of around 220 gigawatts (GW). As the majority of the additional electricity need in the SSA region comes from the rural areas where grid extension cost can be very high and low-efficient, the increase of access mainly relies on mini-grid and isolated off-grid options. On a global level, it is estimated that grid extension is the most suitable option for 30% of rural areas, while mini-grid (65%) or off-grid (35%) solutions would apply for the rest.

4.1.2.3 Other scenarios

In addition to GEA and WEO, the African Energy Outlook 2040 projection has also been chosen as to make comparison with the other projections. While the major objectives of different scenarios share similar trends such as achieving household level of energy access. While the goal setting is relatively lower than that of universal access or energy for all, it would present a more realistic roadmap for Africa in face of currently shortage of financing. Another aspect that distinguishes African Energy Outlook 2040 from the other two is its focus on mobilizing local African resources and efforts to achieve relevant goals, such as regional integration and trade expansion. While it is worth noting that the save from investment costs due to the energy efficiency improvement, the supply-side contribution would be more to the interest of this study.

4.1.3 Projections of energy investment needs in Africa

It has been suggested by AfDB that African countries should look for new financing options to improve the investments in renewable energy as well as modern energy access in Africa. In addition to the existing options, some new financing options include: mobilizing local financing, aid and grants; foreign direct investments; carbon financing, GEF, etc (AfDB, 2009). Africa has also put China on top of the list to integrate renewable energy into their existing economic partnerships. As China has been expanding their manufacturing capacity in renewable energy in recent years, including renewable energy in south-south investments would generate mutual benefits for both economies.

From African institutions' estimates, the African Development Bank has estimated that a total of US$ 547 billion investment would be required to achieve universal access to more reliable electricity supply and cleaner cooking facilities in all the 53 African countries by 2030. The estimates from AfDB is equivalent to over US$ 27 billion per year investment, yet total funding to the energy sector in Sub-Saharan African has averaged only about US$ 2 billion every year (UNIDO, 2009). This section, based on the interpretation of the energy development projections made by GEA, WEO and African Energy Outlook, will provide a quantitative depiction of the roadmap towards achieving a sustainable energy future in Africa.

4.1.3.1 GEA scenarios investment projection

The GEA scenarios' investment projection has been made and analyzed based on the results the GEA Scenario database through inputting different queries. The investment projections for both baseline scenario and GEA-Mix scenario have been demonstrated in Table 4.13 and Table 4.14. As for between 2010 and 2030, which is the period to the interest of this study, The GEA-Mix scenario has a relatively higher investment need in non-fossil areas, while for both scenarios, the supply side investment accounts for the majority of the investment needs.

For GEA-Mix scenario, it is until after 2030 that the demand-side investment started to take off and for a longer time projection, until 2100, the demand side investment is expected to catch up closer. However, only supply side investment is to the interest of this study, which also aligns with the investment needs of the continent in the upcoming 20 years.

Table 4. 12 GEA Baseline Scenario energy investment projection for Africa (Billion US$2005/yr)

Year	2005	2010	2020	2030	2040	2050	2060	2070	2080	2090	2100
Total	**28.02**	**27.83**	**45.97**	**75.06**	**142.00**	**249.12**	**309.24**	**429.45**	**574.31**	**682.15**	**821.74**
Demand-side Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Supply-side Total	**28.02**	**27.83**	**45.97**	**75.06**	**142.00**	**249.12**	**309.24**	**429.45**	**574.31**	**682.15**	**821.74**
Fossil Extraction	18.07	16.53	17.22	25.96	38.69	59.07	76.81	133.66	143.28	130.34	95.70
Fossil Electricity	1.25	2.41	3.56	4.67	16.23	20.77	20.59	17.19	5.35	1.46	0.00
Non-fossil Electricity	3.34	0.78	7.10	15.44	32.40	72.07	81.73	118.20	181.93	274.49	362.59
Electricity Transmission and Distribution (incl.Storage)	4.62	6.38	14.59	21.50	41.17	65.40	79.55	89.90	113.15	158.79	225.24
CCS Total	0	0	0	0	0	0	0	0	0	0	0
Other	0.74	1.73	3.50	7.48	13.51	31.80	50.56	70.50	130.61	117.08	138.21

Data source: GEA Scenario database

Table 4. 13 GEA-Mix Scenario energy investment projection for Africa (Billion US$2005/yr)

Year	2005	2010	2020	2030	2040	2050	2060	2070	2080	2090	2100
Total	**28.02**	**27.81**	**58.07**	**121.64**	**262.89**	**430.55**	**614.04**	**807.82**	**925.74**	**1147.99**	**1333.82**
Demand-side Total	**0.00**	**0.00**	**6.03**	**18.26**	**50.88**	**100.61**	**170.47**	**255.20**	**322.75**	**439.92**	**542.61**
Supply-side Total	**28.02**	**27.81**	**52.04**	**103.38**	**212.01**	**329.94**	**443.57**	**552.62**	**602.99**	**708.07**	**791.21**
Fossil Extraction	18.07	16.53	12.18	15.25	16.53	26.04	28.63	19.92	13.00	14.92	14.99
Fossil Electricity	1.25	2.41	1.74	1.21	1.66	4.03	2.15	1.63	0	0	0
Non-fossil Electricity	4.62	6.38	14.00	21.70	43.21	75.94	113.25	137.28	164.97	201.22	220.08
Electricity Transmission and Distribution (incl.Storage)	0	0	0	1.56	3.78	8.77	9.00	6.18	8.45	11.86	20.08
CCS Total	3.34	0.76	15.34	33.77	74.96	115.21	174.96	253.92	264.10	313.20	353.04
Other	0.74	1.73	8.78	29.89	71.87	99.96	115.58	133.70	152.47	166.87	183.03

Data source: GEA Scenario database

4.1.3.2 WEO scenarios investment projection

Scenario 1: New Policies Scenario

At the global level, in the New Policies Scenario of WEO, it is projected that in order to enable 550 million additional people with access to electricity and provide 860 million people with clean cooking facilities, the total cumulative investment of US$ 296billion in extending modern energy access is needed from 2010 to 2030, equivalent to US$14 billion per year on average.

As illustrated in table 4.15, among the $29 billion investment, US$ 275 billion is expected to go towards electricity, while the rest goes to clean cooking facility access. As for a further division of annual electricity access investment, $7 billion goes to on-grid electricity access while $6 billion goes to mini-grid and off-grid electricity generation.

Table 4. 14 WEO New Policies Scenario projected global investment in modern energy access

Type of energy access	Investment 2010-2030 (US$ in billion)	Investment/ yr (US$ in billion)	Population influenced (million)	Population influenced/yr (million)
Total	296	14	-	-
Clean cooking facility	21	1	860	26
Electricity access	275	13	550	41
On-grid	148	7	-	-
Off-grid and mini-grid	127	6	-	-

Data source: WEO 2011

Scenario 2: Modern Energy for all

The cost of achieving the universal modern energy access goal under the Energy for All Scenario is estimated to be US$ 1 trillion, which is more than three times the US$ 296 billion of the New Policies Scenario estimates and five times of the actual investment in 2009 (WEO, 2011). The investment is expected to be on an annually increase trend. The chart below is a total estimate of the additional investment expected to take place during the 2010-2020 and

2020-2030 periods, which would add up to the US$641 billion additional investment required to achieve the Energy for All scenario.

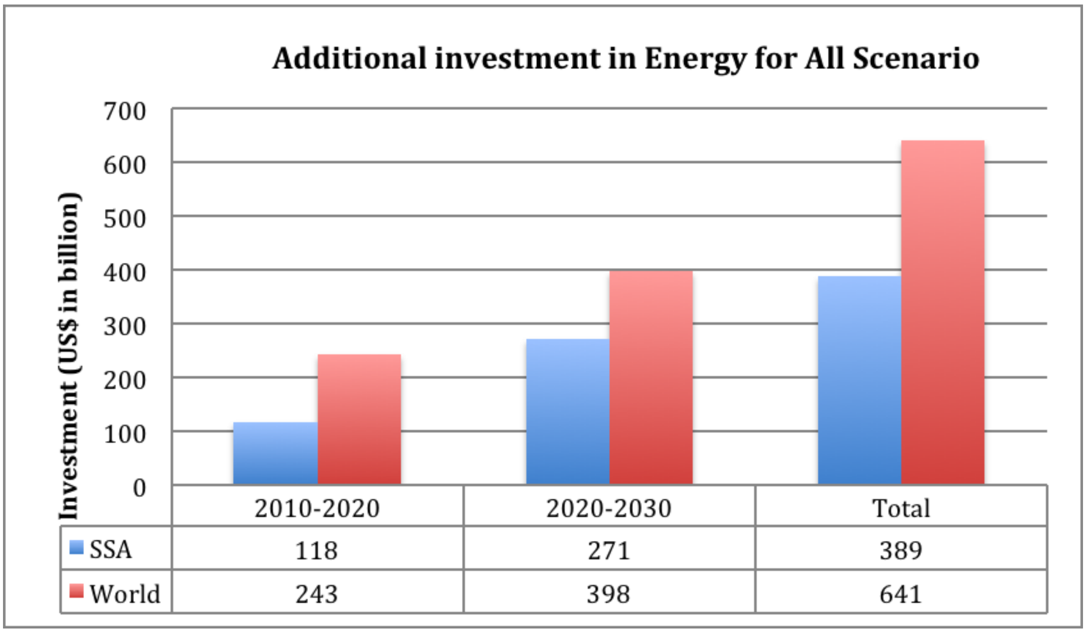


Fig. 4. 8 Additional investment in energy (comparing to New Policies Scenario) in Energy for All Scenario
Data source: WEO 2011

Universal access to electricity

To reach this level of access, around $640 billion additional investment is required globally, all of which coming from the developing countries. Sub-Saharan Africa accounts for 60% of the additional costs, equivalent to US$18.5 billion extra investment annually.

Universal access to clean cooking facilities

In the Energy for All Scenario, US$ 74 billion is required to be invested towards increasing clean cooking facilities access, among which sub-Saharan Africa accounts for US$22 billion. Biogas system is the largest share, while 24% is invested on advanced biomass cookstoves, which is expected to benefit 395 million people in rural SSA. Like the rest of the developing countries, advanced biomass and biogas systems appeal more to the rural area, while most of the stoves are distributed to the urban and peri-urban areas.

To summarize, as shown in Fig. 4.9, in order to meet the Energy for All scenario between 2010 and 2030, the sub-Saharan Africa region needs US$18.5 billion and US$3.5 billion annual investment respectively in access to electricity and access to clean cooking facilities.

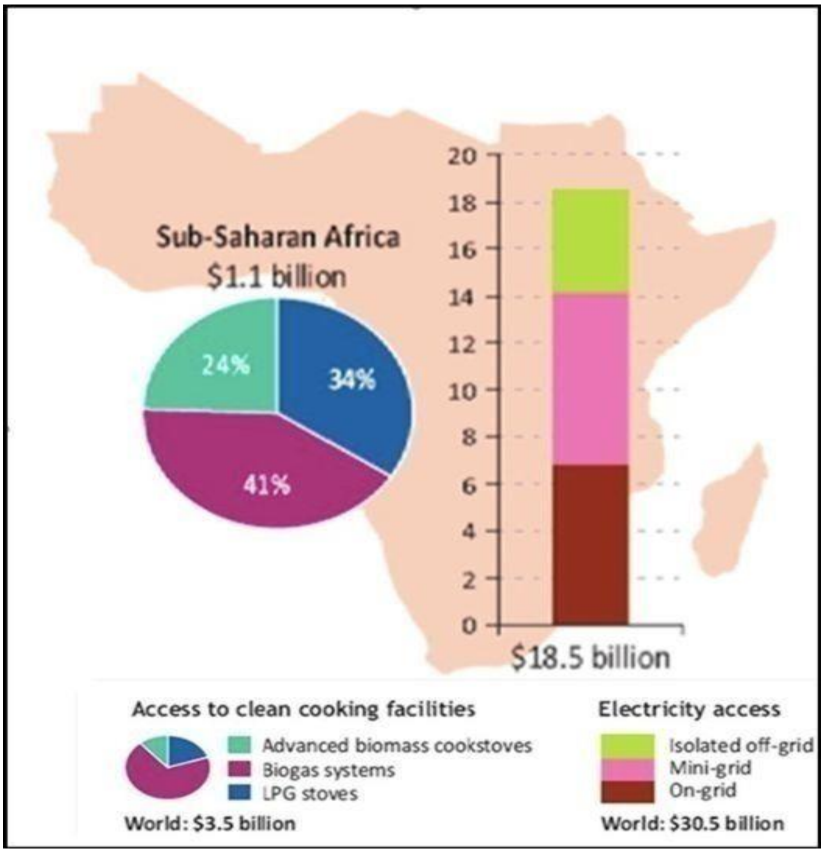


Fig. 4. 9 Summary of WEO Energy for All Scenario
Source: Adapted from WEO 2011

4.1.3.3 Other scenarios

Since the projection on investment differs mainly due to different assumptions and priority settings, what has differentiated the African Energy Outlook 2040 projection different from the other two, is its emphasis on regional integration and trade expansion, to improve energy system efficiency. On the other hand, for the common goals such as the basic modern energy access needs, the projected investment needs align with that from the other two, at a level of $ 4 bln/yr.

4.1.3.4 Scenario summary

The GEA, WEO, African Energy Outlook scenarios have depicted a diversified pool of African's future energy development direction. A summary of the three scenarios' projection on energy investment is demonstrated in Table 4.17.

The GEA-Mix scenario is a comprehensive scenario design, and the database enabled the environmental and social impact to be quantified, thus making the relevant goals achievable and visible under the scenario design. However, despite an obvious increase in energy investment needs, Africa still accounts for a very small share of the world's energy investment at least before 2030. After 2030, the investment in Africa starts to grow faster.

The WEO Energy for All scenarios target at financing energy access for the poor, thus focusing on the energy access financing. The environmental and air pollution impacts were mentioned in the WEO report (2011), but it was confirmed that the increasing energy supply was not causing that much negative environmental impacts as the increasing energy supply would have implied.

The African Energy Outlook by 2040 is a more realistic roadmap for Africa in terms of its goal setting and regional focus. The integration of regional instate trade on the continent is expected to play a bigger role in order to reduce the cost of Africa's energy development. However, to meet its long-term goal, technical and financing supports are still in urgent demand from beyond the continent.

As shown in Table 4.15, the financing need estimations are different, due to different assumptions and priority settings made by different scenarios. However, the financial need for achieving modern energy access tends to be similar, ranging between $4-6 billion US/yr. The results of the three major scenarios share some common trends and implications which will be further discussed in section 4.4

Table 4. 15 Sustainable energy scenarios investment projection (Data source: GEA, WEO, NEPAD and AfDB and own calculations)

		Year	**2010**	**2020**	**2030**	**Annual average**	**Base-End Year**
Global Energy Assessment (GEA), 2012	**Baseline Scenario**	**Supply-side**	**27.83**	**45.97**	**75.06**	**49.62**	**2005-2050 (extended to 2100)**
		Fossil Extraction	16.53	17.22	25.96	**19.91**	**Common assumptions**
		Fossil Electricity	2.41	3.56	4.67	**3.54**	GDP growth rate
		Non-fossil Electricity	0.78	7.10	15.44	**7.77**	Population growth:
		Electricity Transmission and Distribution (incl.Storage)	6.38	14.59	21.50	**14.16**	**GEA-Mix goals**
	GEA-Mix Scenario	**Supply-side**	**27.81**	**52.04**	**103.38**	**61.08**	Energy access
		Fossil Extraction	16.53	12.18	15.25	**14.65**	Pollution control
		Fossil Electricity	2.41	1.74	1.21	**1.79**	Climate change mitigation
		Non-fossil Electricity	0.76	15.34	33.77	**16.62**	Energy security
		Electricity Transmission and Distribution (incl.Storage)	6.38	14.00	21.70	**14.03**	
World Energy Outlook (WEO) 2011 special excerpt- Energy for all: financing access for the poor (unit: Billion US$2010/year or US$2010)	**New Policies Scenario**	**Year**				**Annual average**	**2010-2030**
		World electricity access				**14**	**Assumptions**
		Clean cooking facility				1	Access objective set at household level
		Electricity access		–		13	**Access for all objectives**
		On-grid				7	Universal modern energy access by 2030
		Off-grid and mini-grid				6	Household level:1) Having access to reliable and affordable cooking facilities 2) A first connection to electricity, then increasinglevel of electricity consumption to reach regional average level
		Sub-Saharan Africa				6.31	
	Modern Energy for All Scenario	**Year**	**2010-2020**	**2020-2030**	**Total**	**Annual average**	
		World	24.3	36.2	641	**33.33**	Note: Modern energy for all estimates are based on the New Policy Scenario level
		Africa	11.9	27.1	390	**18.33**	
		Sub-Saharan Africa	11.8	27.1	389	18.33	
		Clean cooking facility	1.1		22	1	
		Electricity access	18.5		370	17.30	
Africa Energy Outlook 2040 (NEPAD and AfDB), 2011	**Moderate Integration Scenario**	**Year**	**2014-2020**	**2021-2030**	**2031-2040**	**Annual average**	**2010-2040 (Increase access from 40% to 69%)**
		Access	**4.01**	**4.80**	**3.87**	**4.23**	Average GDP growth: 6.2%
		Generation	20.33	39.92	38.68	32.30	**General goal:** Continent ntegration and energy access
		Interconnection	7.76	4.85	0.67	4.68	**Objectives:** 1)Develop hydroelectric project 2)Implement high capacity oil refineries and oil pipeline projects 3)Develop renewable energy resouces
		Pipeline and Refinery	1.80	1.20	1.50	1.50	
		Total	33.59	49.66	44.56	**42.71**	

4.2 Profile of China's FDI in Africa

China's 12th Five-Year Plan, which was approved in March 2011 put forward the goal of "green development" for China and strengthened the "Go out" strategy which aims at encouraging Chinese companies to invest overseas (WWF 2011). The nexus of these two otherwise separate priorities offers an opportunity for China and Africa to work collaboratively towards the common goal of sustainable development, which was also stated in the 2009 China-Africa Cooperation Forum (FOCAC) declaration.

In the past decade, China has increased its FDI presence in the world, including Africa. On the other hand, China has also been a role model in achieving significant success in improving the access to electricity for its rural population and in the dissemination of clean cooking facilities as well as other clean technology for rural development. It is reasonable to expect China to share the successful experience with African countries in the process of reinforcing FDI towards the continent.

Section 4.2 depicts a profile of China's FDI, especially focusing on Africa. The profile includes an introduction of the administrative system involved in China's FDI, the historical trend, as well as the sectoral and geographical distribution of China's FDI in Africa.

4.2.1 Stakeholders involved

In order to have a clear image of China's OFDI, it is important to understand how FDI works in China's political and economic system. The major stakeholders involved in the decision making and project implementing process can be grouped into three categories, including government (ministries), state agencies and enterprises. A general relationship between different stakeholders can be seen in the following flow chart as shown in Fig. 4.10.

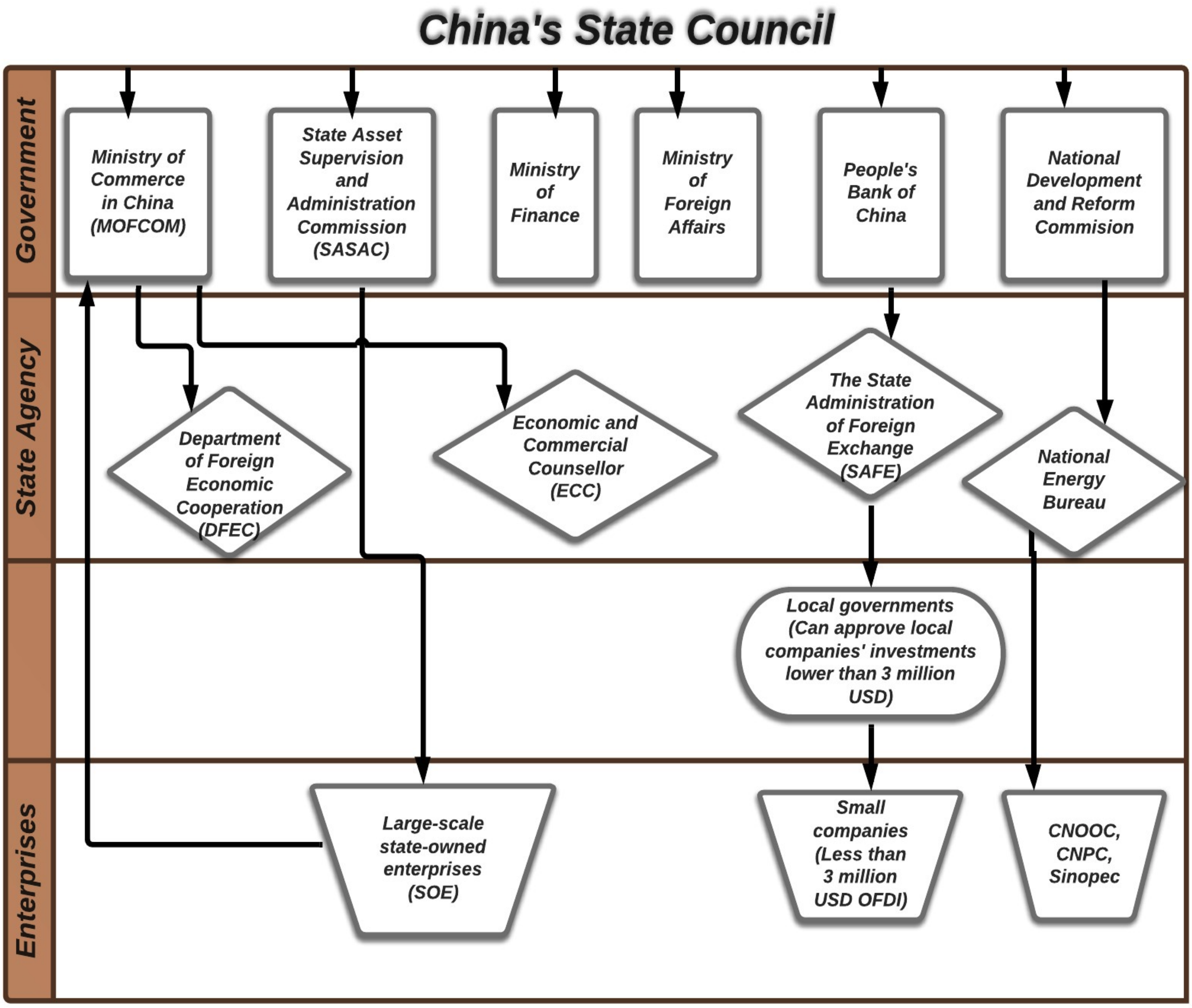


Fig. 4. 10 Administrative structure of China's FDI system
Source: (Adapted from Lugt, 2011)

In addition to the institutions and enterprises listed in the figure above, there are also other stakeholders playing important roles in facilitating China's FDI in Africa. Two out of three major policy banks in China, namely China Development Bank (CDB) and Export-Import Bank of China (Ex-Im Bank), are involved in financing China's FDI, as part of their respective role in promoting infrastructure development and foreign investment. In fact, Ex-Im Bank of China is one of the most important financiers of China's large-scale FDI deals.

The China-Africa Cooperation Forum (FOCAC), which was first held in 2000 in Beijing, serves as an important channel for collective consultation and expanding bilateral understanding and cooperation. The set-up of China-Africa Development Fund (CADFund) is another milestone, which was initially proposed at the 2006 FOCAC ministerial conference among one of the eight concrete measures to promote Sino-Africa partnerships. The CADFund was set up in 2007, and the total amount of financing is expect to reach 5 billion USD ultimately. By the end of 2013, a total of 3 billion USD funding had been directly provided by China Development Bank. The fund, on one hand set up on a high profile, on the other hand is an equity investment fund that is "operated independently and based on market economy principles" (CADFund). This initiative marks a pioneering step in China's foreign direct investment in Africa, which may contribute to differentiating and distinguishing FDI from the traditional mode of aid and loans (CADFund), while the distinction between investment and aid has mostly been blurred in China's FDI, especially those funded by a state source.

4.2.2 Increasing but still small scale

Since the establishment of the "Go out" strategy in 2000, China's OFDI has been increasing steadily, with a compound annual growth rate of 44.6% and is playing a leading role among developing economies (MOFCOM, 2012). In 2011, China ranked 6th in terms of Outward FDI flows and 13th in terms of OFDI stock among all the economies in the world. As part of the commitment made by MOFCOM in China's 12th Five Year Plan, China's OFDI is expected to reach 150 billion by 2015, with an annual growth rate of at least 17% per year.
By the end of 2011, Chinese OFDI stock had reached $ 424.78 billion and 180,000 overseas enterprises have been set up across 177 countries, among which there are 53 countries located in Africa. Even during the financial crisis between 2008 and 2009, China's OFDI flow was on a rise, though in the recent few years the growth has slowed down and the growth rate was 8.5% between 2010 and 2011. The only exception of the increasing trend was that according to UNCTAD data as shown in Fig. 4.11, the 2011 OFDI flow of China was $65.12 billion,

according to which there was a decrease from 2010 to 2011; while the same statistics from MOFCOM is $74.65 billion as shown in Table 4.16, which is higher than 2010.

Table 4. 16 China and World OFDI flow and stock since the establishment of China's OFDI recording system (Billion USD)

Year	2003	2004	2005	2006	2007	2008	2009	2010	2011
China's OFDI flows	2.85	5.50	12.26	21.16	26.51	55.91	56.63	68.81	74.65
Share of China in World OFDI flow	0.50%	0.59%	1.38%	1.50%	1.21%	2.84%	4.82%	4.74%	4.41%
China's OFDI flow to Africa	0.07	0.32	0.39	0.52	1.57	5.49	1.44	2.11	3.17
Share of Africa in China's OFDI flow	2.62%	5.77%	3.19%	2.46%	5.94%	9.82%	2.54%	3.07%	4.25%
China's OFDI stock	33.20	44.80	57.20	90.63	117.91	183.97	245.75	317.21	424.78
Share of China in World OFDI stock	0.33%	0.38%	0.46%	0.58%	0.61%	1.13%	1.27%	1.52%	2.01%
China's OFDI stock in Africa	0.49	0.90	1.60	2.56	4.46	7.80	9.33	13.04	-
Share of Africa in China's OFDI stock	1.48%	2.01%	2.79%	2.82%	3.78%	4.24%	3.80%	4.11%	-

Data souce: MOFCOM, UNCTAD, and calculations

However, having a closer look at China's OFDI data in comparison with the global OFDI, it is noticeable that China still comprises a very small part of the world total OFDI, like mentioned by Lugt et al. (2011) that "Chinese FDI is still in its infancy". China's share did not reach 1% until 2005, and 4.82% in 2009 marked the highest record of China's OFDI share in the world. According to UNCTAD (2012), the world's total OFDI flow was 1694.4 billion in 2011 and the total OFDI stock reached 21,170 billion, against which China's share is only 4.4% and 2% respectively.

While MOFCOM only started to publish China's FDI Statistics Bulletin in 2003, a longer historical record could be tracked from the UNCTAD FDI database as shown in Fig. 4.6. China's OFDI flow reached 4 billion at certain years in the 1990s, but a steady growth only took off after the 2000s. The significant break point also corresponds with the timing of China's establishment of "Go out" policy, which was included in China's 10th Five Year Development Plan in 2000.

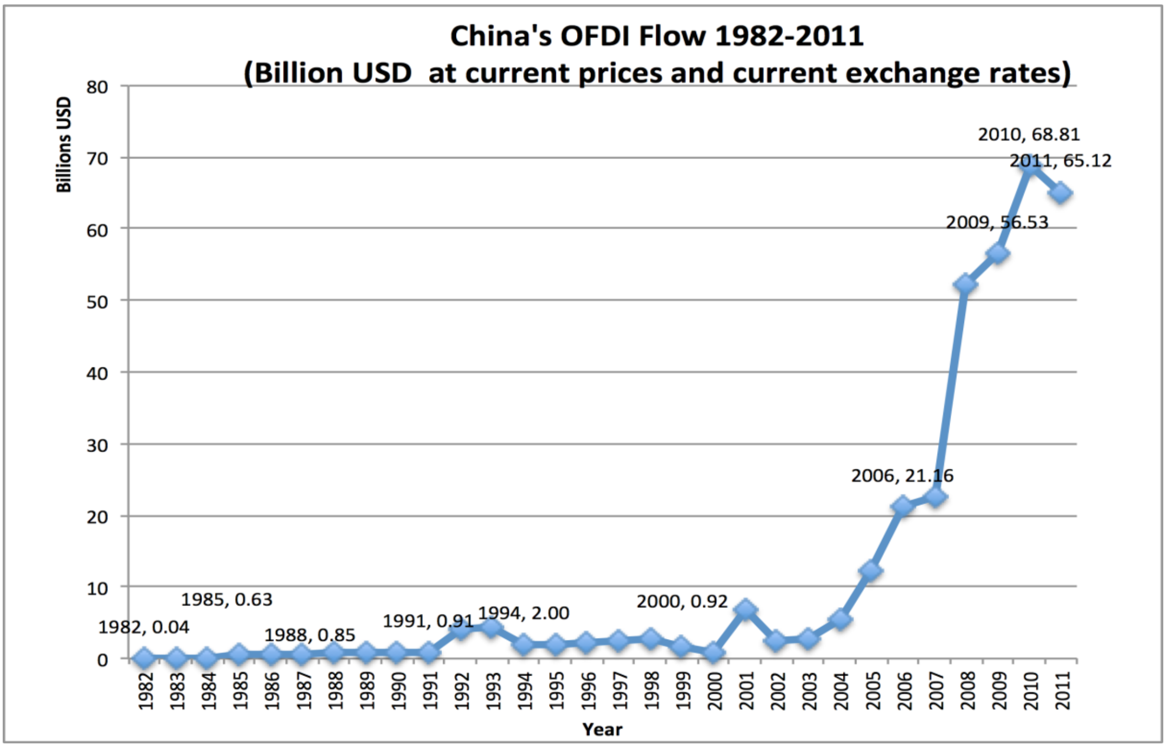


Fig. 4. 11 China's historical OFDI flow, 1982-2011
Data source: UNCTAD FDI database

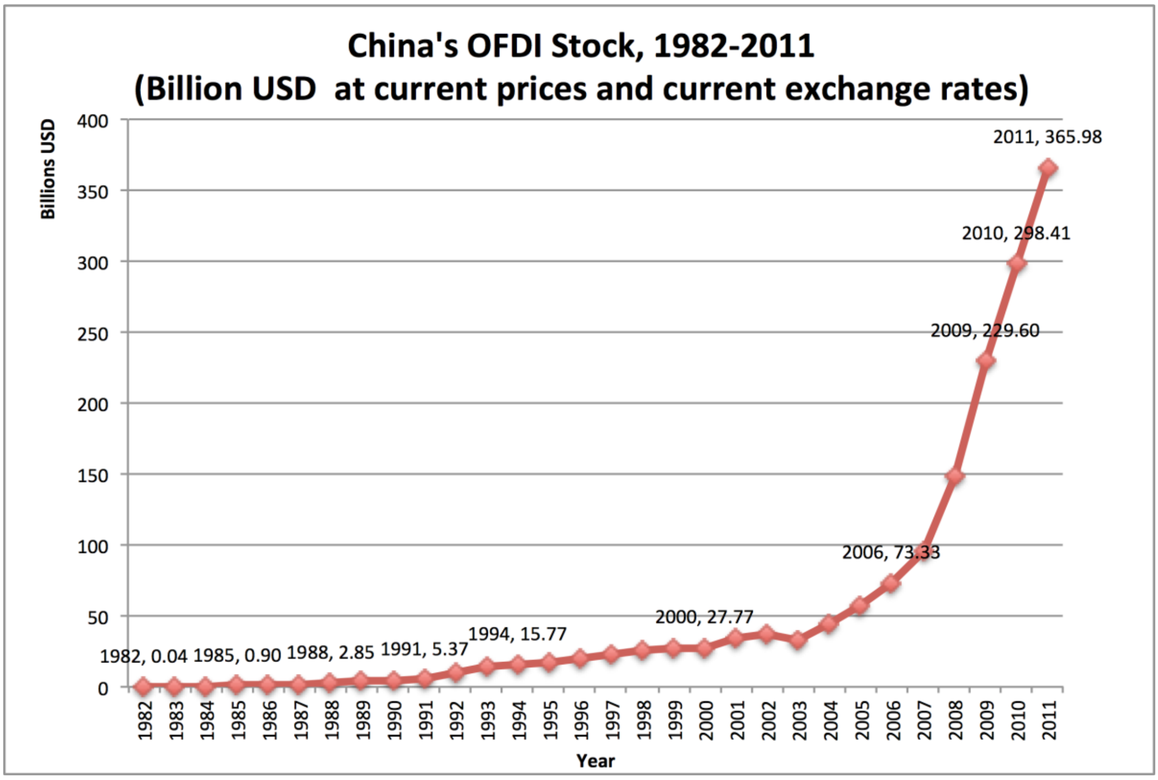


Fig. 4. 12 China's historical OFDI stock, 1982-2011
Data source: UNCTAD FDI database

At the same time, the amount of China's OFDI in Africa has been constantly growing, except during the financial crisis between 2008 and 2009, when China's OFDI flow to Africa dropped from 5.49 billion USD to 1.44 billion USD. The 2011 level of China's OFDI flow to Africa is almost ten-fold that of the 2004 level. Despite of the quantity growth, the share of Africa in China's total OFDI flow remains below 5% and did not increase significantly since 2003.

In addition, as shown in Table 4.17, the share of China's FDI in Africa's total inward FDI has been rising. In 2008, the share reached almost 10%, while the figure then dropped to 2.73% amidst the 2008-2009 financial crisis. China's FDI in South Africa has contributed substantially to the rise of China's FDI in Africa in 2008. From 2009 to 2011, another rising trend is on the track and can be expected to surpass the 2008 level in the upcoming few years

Table 4. 17China's OFDI flow and stock in Africa's inward FDI

Year	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
China's OFDI flow to Africa	0.07	0.32	0.39	0.52	1.57	5.49	1.44	2.11	3.17
Africa's Inward FDI flow	18.19	17.36	30.50	36.78	51.48	57.84	52.64	43.12	42.65
Share of China in Africa's IFDI	0.41%	1.83%	1.28%	1.41%	3.06%	9.49%	2.73%	4.90%	7.43%
China's OFDI stock to Africa	0.49	0.90	1.60	2.56	4.46	7.80	9.33	13.04	-
Africa's Inward FDI stock	201.47	238.77	260.49	314.94	392.87	391.08	488.64	561.35	569.56
Share of China in Africa's IFDI	0.24%	0.38%	0.61%	0.81%	1.14%	2.00%	1.91%	2.32%	-

Data source: MOFCOM and UNCTAD, 2006-2010 China Statistical Bulletin on Outward FDI; MOFCOM, 2012, Report on development of China's outward investment and economic cooperation
*The 2011 data for China's OFDI stock in different countries is not available in the 2012 MOFCOM report, thus the 2011 data for China's OFDI stock in Africa is missing.

4.2.3 Sectorial and geographical distribution

The sectorial distribution of China's OFDI has been on a dynamic trend. In addition to the local economies' characteristics, it is also related to the transformation of China's own economic development plan and the increasing involvement of private companies in comparison with more than 10 years ago, when state-owned enterprises dominated the field.

Due to lack of aligning with international standard in the FDI statistics recording, the sectorial distribution statistics of China's OFDI from MOFCOM FDI Statistical Bulletin is not a sufficient to interpret China's OFDI in the energy sector, which is to the interest of this study. However, the data is presented below in Table 4.18, and the most relevant part, which is mining, production and supply of electricity, as well as gas and water has been highlighted.

Table 4. 18 Distribution of China's OFDI flow by industry, 2004-2010 (Billion USD)

All sectors/industries	2004	2005	2006	2007	2008	2009	2010
Total	5.50	12.26	21.16	26.51	55.91	56.63	68.81
Primary							
Agriculture, forestry, husbandry and fishing	0.29	0.11	0.19	0.27	0.17	0.34	0.53
Mining	**1.80**	**1.68**	**8.54**	**4.06**	**5.82**	**13.34**	**5.72**
Secondary							
Manufacturing	0.76	2.28	0.91	2.13	1.77	2.24	4.66
Construction	0.05	0.08	0.03	0.33	0.73	0.36	1.63
Services							
Construction	0.05	0.08	0.03	0.33	0.73	0.36	1.63
Transport, Storage and Post	0.83	0.58	1.38	4.07	2.66	2.07	5.66
Production and supply of electricity, gas and water	**0.08**	**0.01**	**0.12**	**0.15**	**1.31**	**0.47**	**1.01**
Other sectors include leasing and commercial services, financial services, information transmission, real estate, research, residential services, public							

Data source: MOFCOM, 2011

Another feature of China's FDI lies in its geographical distribution. China's average annual OFDI flow between 2004 and 2010 and China's OFDI stock in 2010 have been ranked by destination country to depict this feature. China's OFDI flow in the top five recipient African countries account for almost half of China's total OFDI on the continent. The result for OFDI stock is even higher. Table 4.19 presents China's historical OFDI flow and stock in the top ten recipient African countries. In order to compare with the assertion in previous' studies that China's FDI is heavily focused on resource-rich, especially oil-rich countries, the oil supply and energy development condition of these ten countries have been examined. It can be seen that among the top ten countries, three are highly rich in oil supply. But there are also countries such as Zambia and Ethiopia which lack access to oil resources

Table 4. 19 China's OFDI flow in top 10 African recipient countries (Million USD)

Rank	**Country**	**Region**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
1	South Africa	Southern	17.81	47.47	40.74	454.41	4807.86	41.59	411.17
2	Nigeria	Central	45.52	53.3	67.79	390.35	162.56	171.86	184.89
3	Algeria	Northern	11.21	84.87	98.93	145.92	42.25	228.76	186
4	Zambia	Southern	2.23	10.09	87.44	119.34	213.97	111.8	75.05
5	DR Congo	Central	11.91	5.07	36.73	57.27	23.99	227.16	236.19
6	Niger	Western	1.53	5.76	7.94	100.83	-0.01	39.87	196.25
7	Sudan*	Eastern	146.7	91.13	50.79	65.4	-63.14	19.3	30.96
8	Egypt	Northern	5.72	13.31	8.85	24.98	14.57	133.86	51.65
9	Ethiopia	Eastern	0.43	4.93	23.95	13.28	9.71	74.29	58.53
10	Angola	Central	0.18	0.47	22.39	41.19	-9.57	8.31	101.11
Africa total			317.43	391.68	519.86	1574.31	5490.55	1438.87	2111.99
Sub-total 1			88.68	200.8	331.63	1167.29	5250.63	781.17	1093.3
Percentage 1			28%	51%	64%	74%	96%	54%	52%
Sub-total 2			243.24	316.4	445.55	1412.97	5202.19	1056.8	1531.8
Percentage 2			77%	81%	86%	90%	95%	73%	73%

Data source: MOFCOM, 2011; UNCTAD, 2012

In addition, China's top OFDI destinations in Africa also align with the global OFDI trend towards Africa. Among the top 10 FDI recipient countries in Africa, 7 of them are also on the list of China's top 10 list, namely South Africa, Nigeria, Egypt, Algeria, Zambia, DR Congo and Sudan. Table 4.20 includes the ranking of the countries in terms of China's OFDI and their total inward FDI stock.

It is worth noting that there has been some significant increase in China's FDI towards South Africa. From 2007 to 2010, China almost doubled its FDI stock in South Africa. Besides, there are countries such as Ethiopia and Niger, which are neither oil rich nor traditional popular FDI destinations according to their inward FDI stock statistics, while they have been receiving increasing FDI from China in recent years.

Table 4. 20 China's OFDI stock (2010) and share in top 10 African recipient countries (Billion USD)

Country	China's OFDI	Rank 1*	Total IFDI	Rank 2**	China's share
South Africa	4.15	1	153.13	1	2.71%
Nigeria	1.21	2	60.33	3	2.01%
Zambia	0.94	3	10.95	10	8.62%
Algeria	0.94	4	19.2	7	4.88%
DR Congo	0.63	5	3.99	24	15.81%
Sudan*	0.61	6	20.11	6	3.05%
Niger	0.38	7	2.25	27	16.86%
Ethiopia	0.37	8	4.26	22	8.64%
Angola	0.35	9	11.9	9	2.96%
Egypt	0.34	10	73.1	2	0.46%

*Rank 1 is based on China's OFDI in Africa

**Rank 2 is based on recipient countries' totalIFDI

Data source: MOFCOM, 2011; UNCTAD, 2012

4.3 China's energy investment in Africa

China's FDI in Africa has grown more than ten-fold in the past decade along with the intensified political and socio-economic ties between China and Africa. Traditionally, the mention of China's energy related FDI has always been linked with oil and gas in existing literature. As a matter of fact, the mining sector (including petroleum, mineral and other natural resources) indeed has a major share in China's FDI. The top list of Chinese financiers is also occupied by the three national oil corporations (NOC) namely Sinopec, ChinaPetrol and CNOOC. However, petroleum is just one of the many fields that China's FDI has been directed to. In addition, most of the petroleum investment projects are located in North Africa, where the population has achieved almost universal electricity access. While it is possible that China's FDI in petroleum may have positive impact on regional and global energy supply or even energy security, the emphasis of this study is to examine and predict China's role in Africa's sustainable energy development, where empowering the power deprived sub-Saharan Africa region is of more relevance. Thus this section would mainly focus on the non-petroleum power sector FDI projects among China's FDI in Africa.

Section 4.3.1 will give a general introduction of China's power sector FDI. Section 4.3.2 will present the findings on China's power sector infrastructure investments in Africa based on project-level data from different sources. In addition China's FDI in non-hydro renewable will be further explored in section 4.3.3.

4.3.1 China's FDI in the power sector

Based on MOFCOM (2012)'s sector definition and statistics, the share of China's OFDI in power sector among all other sectors has been tiny as can be seen from Fig. 4.13. It is worth noting that, although not clarified, the power sector investment recorded by MOFCOM mainly refers to that from state-owned-enterprises (SOEs). From 2004 to 2007, China's power sector FDI almost doubled, while from 2007 to 2011 the growth was more than 10-fold. However, at the same time, China's FDI in other sectors has also been growing dramatically, thus the share of power sector in China's total OFDI did not increase as much. But considering that China has also been struggling and exploring its own way towards a more reliable and secure energy system in the past decade and it was only after China had undergone a systematic reform in its power sector in early 2000s that the country's power sector started to "go out" and get more actively involved in FDI (MOFCOM 2012), it is reasonable to expect power sector's low and volatile share in the total OFDI.

Although MOFCOM started the FDI recording and information disclosure system in 2006, the sectorial level data has only started to be disclosed since 2011, thus limiting the availability of comparable data. Based on the combined information from power sector data in China's Statistical Bulletin on OFDI in 2011 and the newly established official Investment Project Information Database by MOFCOM, Chinese state-owned companies have invested in 476 power related projects world wide in 2010 and 2011.

The most popular destination of the power sector FDI is Southeast Asia, where 27 projects were located in. Fig. 4.14 presents the distribution of these 46 projects in terms of investment type and scale. Among the four types of FDI, namely Greenfield investment, Merge and acquisition (M&A), Build-Operate-Transfer (BOT) and Build-Own-Operate-Transfer (BOOT), M&A turns out to be the most popular type, in terms of both project number and investment value, while BOOT is the least common, with only 3 BOOT projects accounting for 1% of the total value of power sector investment. Among the 47 projects, 3 are located in Africa.

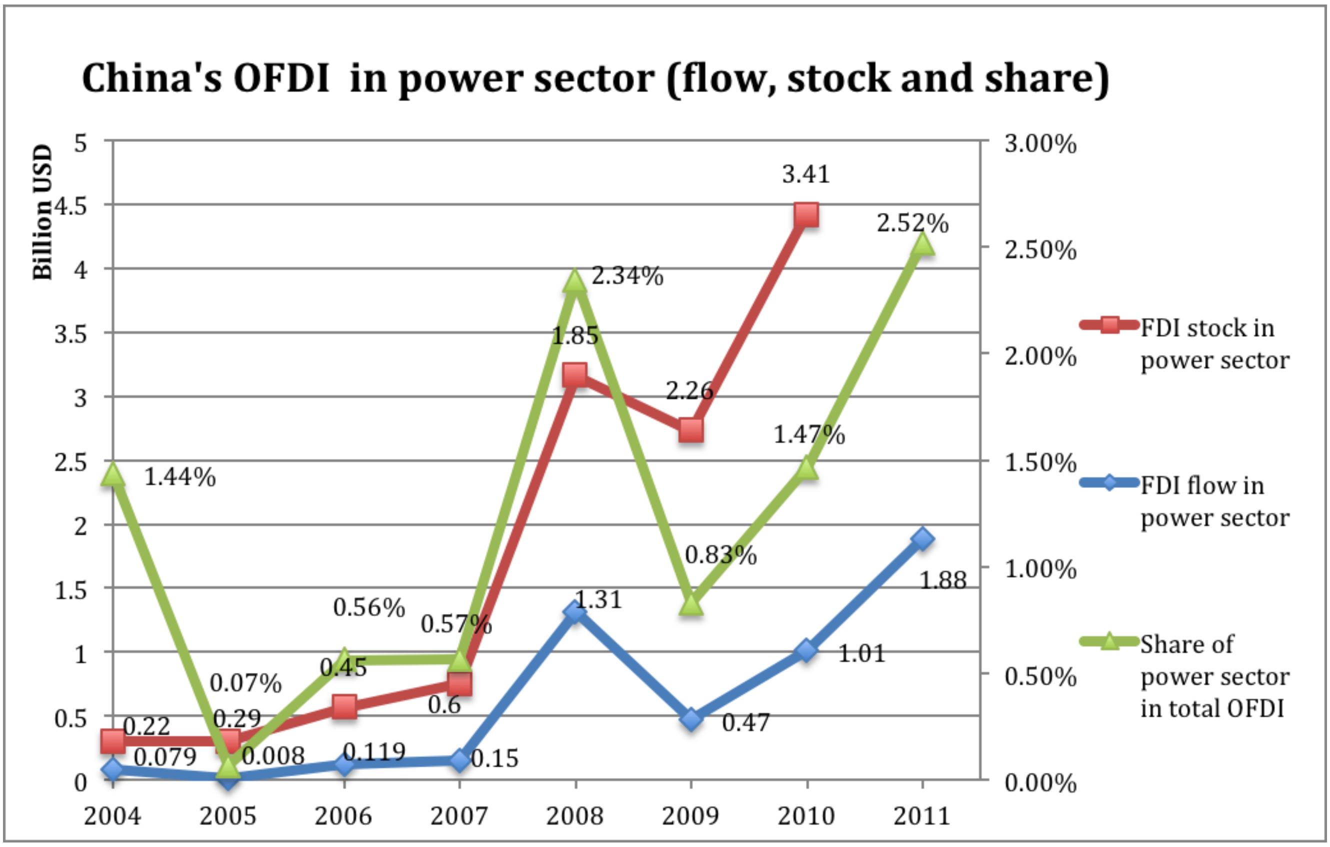


Fig. 4. 13 China's OFDI in power sector, stock and share (Billion USD, %)
Data source: MOFCOM 2012 and calculations

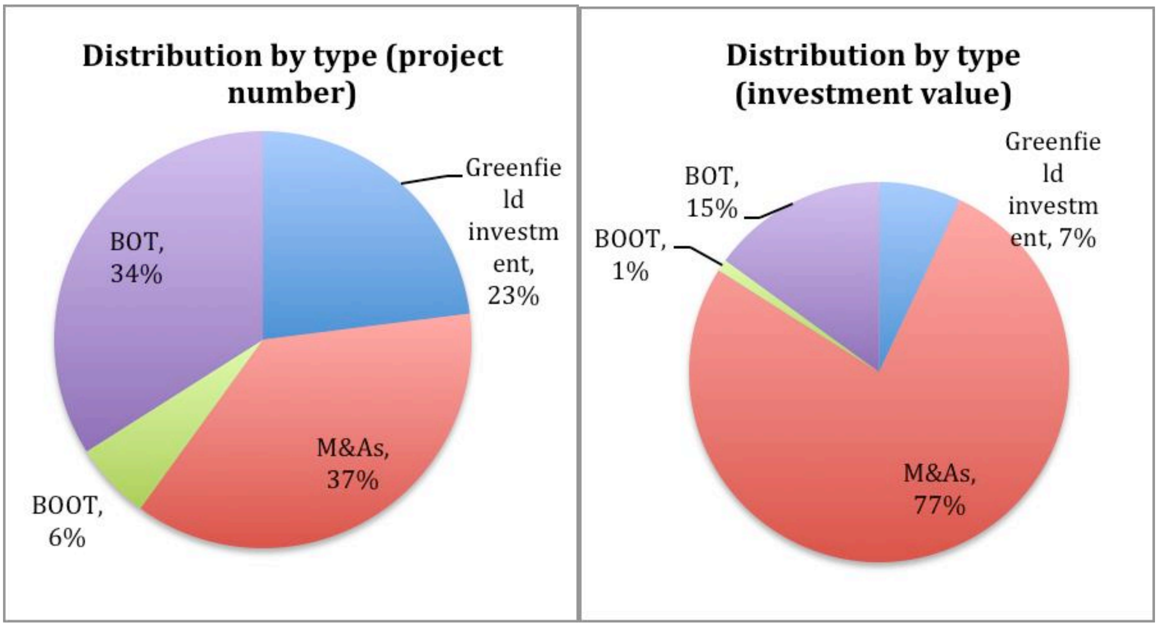


Fig. 4. 14 Distribution of China's power sector OFDI project by type, 2010-2011
Data source: MOFCOM 2012 and calculations

According to the available aggregate power sector FDI data between 2004 and 2011, China's FDI in the sector has been volatile as shown in Fig 4.13, and the growth rate from year to year is even more volatile as shown in Fig 4.15 ranging from −90% to 13.88. But from 2009 on, in contrast with the first half of the decade, the power sector OFDI flow has been growing more steadily and tends to follow a linear growth trend. The compounded growth rate (as shown in Fig. 4.10) of China's total OFDI and the OFDI in power sector have been calculated with year 2004, which is the starting year of China's official FDI statistics record, as the base year of calculation. By calculating compounded rate, it looks at the average rate of growth assuming that the growth is spread across the period at a constant rate. According to the result, in the last few years when the growth trend tends to be more stable, the compounded growth rate of the power sector is gradually rising and beginning to surpass that of the total OFDI, while the compounded growth rate of total OFDI tends to be dropping gradually.

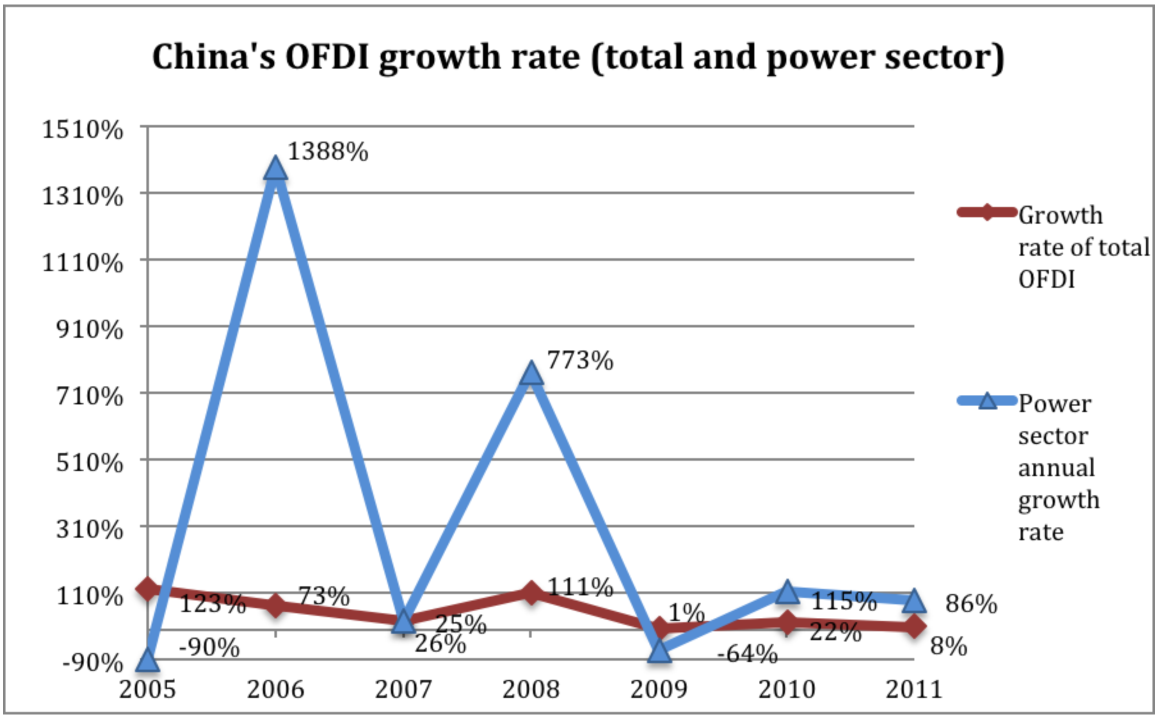


Fig. 4. 15 China's OFDI growth rate (total and power sector), 2005-2011
Data source: MOFCOM 2012 and calculations

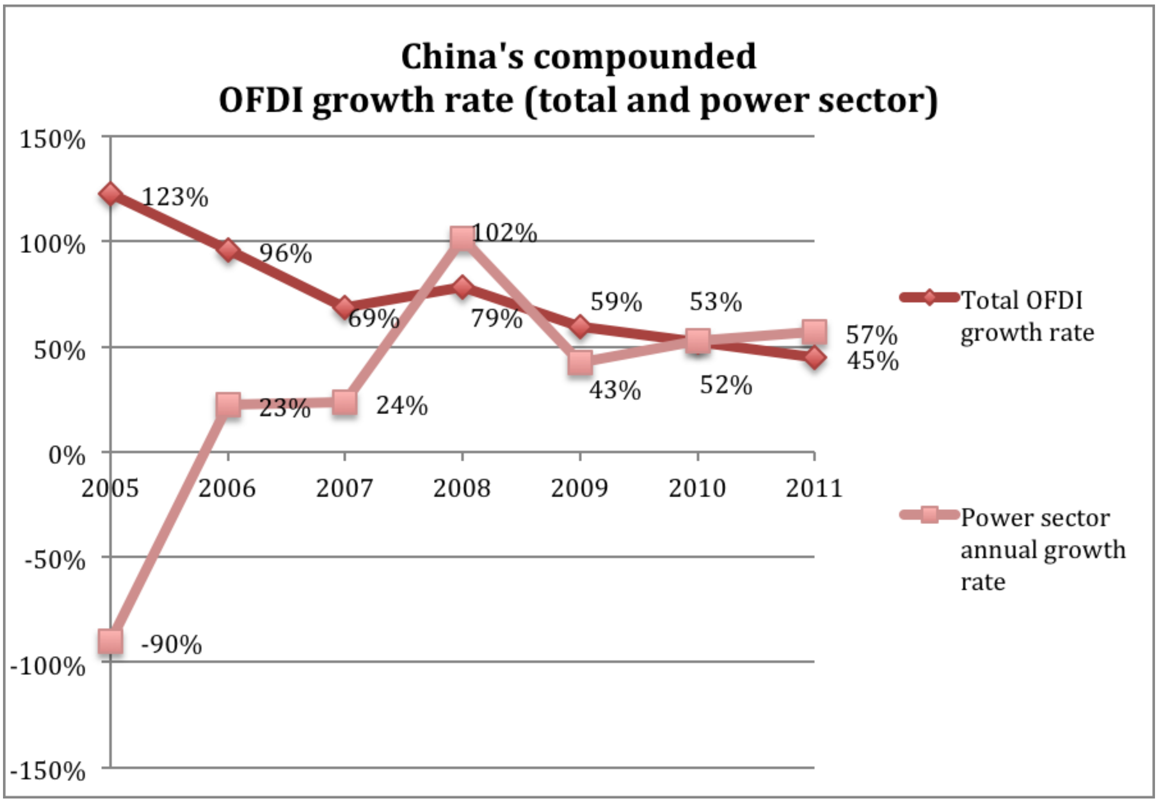
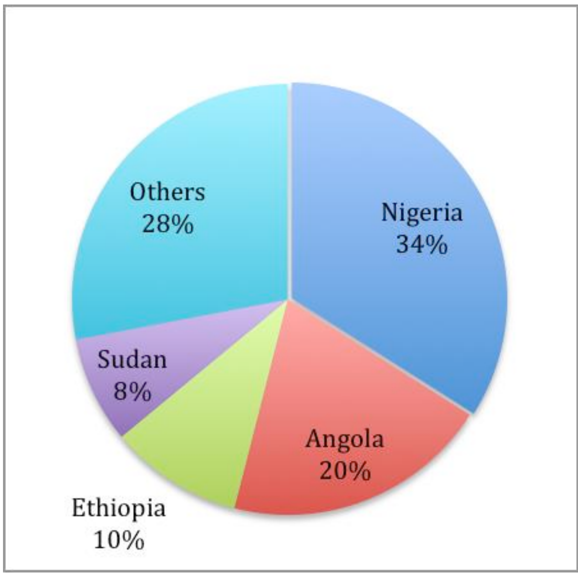


Fig. 4. 16 China's compounded OFDI growth rate (total and power sector), with 2004 as the base year
Data source: MOFCOM 2012 and calculations

4.3.2 China's energy infrastructure investment in Africa

According to Africa Infrastructure Country Diagnostic (AICD), a large share of China's FDI in Africa has been devoted to infrastructure projects across different sectors including power, building, road, etc. Like the geographical and sectorial distribution of China's total FDI in Africa, infrastructure financing has been distributed among several major countries and sectors, which can be seen in Fig. 4.17. These large-scale infrastructure projects have been contributing to Africa's social and economic development, among which the power sector is taking the leading role. However, as there has been no systematic disclosure from Chinese official sources on China's overseas infrastructure projects, most of the interpretation in this part will be based on project-based data collection. Project-level data have been sourced from World Bank Private Participation Infrastructure (PPI) database, International Rivers Network's Chinese Dams in Africa dataset, the AidData database, two other Chinese official sources including MOFCOM and China-Africa Development Fund and the investor companies' reports or websites.



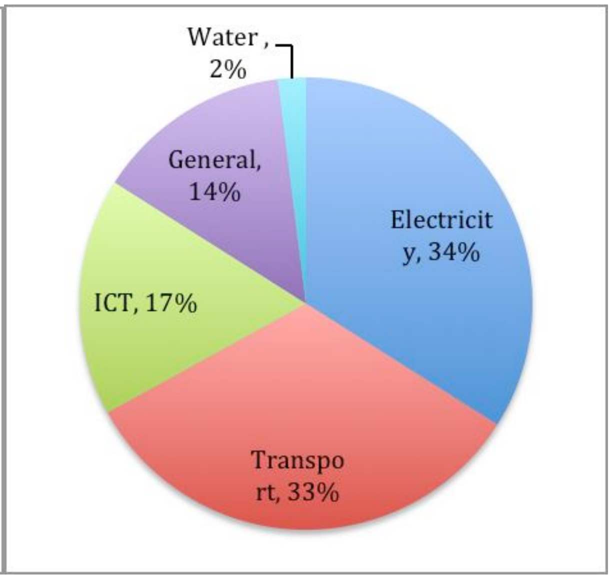


Fig. 4. 17 Distribution of China's infrastructure financing in Africa, by country and sector
Data source: Foster, et al. 2008

Estimates based on World Bank PPI database (2002-2007)

The power sector attracts the largest amount of Chinese infrastructure financing in Africa among other sectors. According to China's OFDI Statistical Bulletin (2006-2010), among the top 10 Chinese infrastructure project contractors, 6 are from the electricity sector, including Sinohydro, China Geo-engineering Corporation, China Gezhouba Group Corporation, Shandong Electric Power Construction Corporation, China National Machinery&Equipment Import&Export Construction Corporation, as well as China National Aero-technology Import&Export Cooperation. So far, these power companies in China have been playing a major role in China's infrastructure investment in Africa.

According to the analysis of Foster *et al*. (2009) based on the World Bank PPI database, China's commitment in power projects in Africa adds up to 5.34 billion USD from 2001 to 2007, distributed in electricity generation, including hydropower and thermal generation, as well as electricity transmission and distribution. Such level of investment is equivalent to a

0.76 billion USD of annual supply-side energy investment. In terms of project quantity and amount of investment, Table 4.21 makes a summary of the relevant data.

Table 4. 21 Quantity, value and capacity of China's energy investment projects in Africa (2002-2007)

Power project type and status		Generation		DTG**	Total
		Hydro	Thermal		
Project number	Total	15	12	9	36
	CUC*	9	7		
	PS*	6	5		
Project size (Billion USD)	Total	9.19	3.72	0.32	13.23
	CUC	2.93	1.78		
	PS	6.26	1.94		
Installed capacity (GW)	Total	8.32	3.63	>2146km	11.95
	CUC	2.63	1.76		
	PS	5.70	1.87		
China's commitment (Billion USD)		3.29	1.58	0.472	5.34

Notes:*CUC stands for Completed or under-construction, PS stands for Proposed or suspended; **DTG stands for distribution, transmission, and general
Data source: World Bank PPI database, as cited by Foster *et al*. 2009 and calculations

There are two distinctions worth noting in the database. The first distinction is between China's investment commitment and the size of the project. In some cases, China's investment commitment equals the size of the project, while sometimes China's investment accounts for certain percentage of the project need. In table 4.21 the project size of electricity distribution and transmission is smaller than China's commitment, as a result of lacking the project size information of certain projects. Another distinction lies in the status of the investment. As the World Bank PPI database is set up based on different sources, certain projects may still be in the early stage of agreement or proposal. Such commitments may have an implication for China's future investment, but does not necessarily reflect China's existing investment capacity.

Estimates based on International Rivers' dataset (from before 1990s until 2012)

Another dataset that has been referred to in this study is the *Overseas dam building by Chinese companies and financiers* database, which has been built up by the International Rivers Network organization based on media reports, government reports and company information to provide an approximate image of the scale and distribution of China's dam project and includes Chinese dam building projects dating from before 1990s till 2012. As shown in Fig. 4.18, Africa is by far the second largest destination for Chinese overseas dam construction projects, while Asia, especially Southeast Asia is the largest host region. A further summary of China's hydropower dam projects in Africa is presented in Table 4.22, in comparison with China's hydropower engagement in the rest of the world.

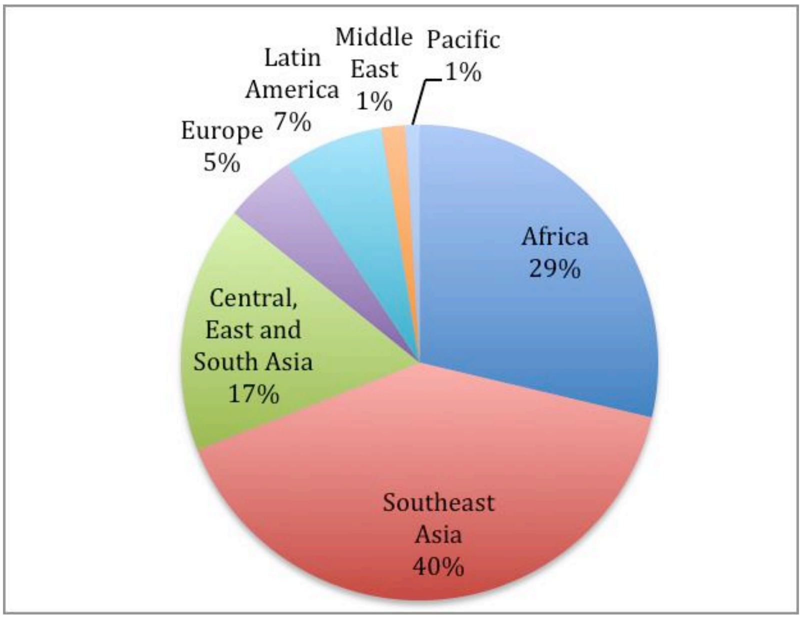


Fig. 4. 18 Distribution of China's dam building projects by region (until 2012)
Data source: International Rivers Network *Chinese Dams in Africa* database

Among the recorded 311 dam projects across 74 countries, 89 are located in Africa across 29 countries, and 69 of them are for hydropower purpose while the rest are for irrigation, flood control or water supply purposes. There are also a few multipurpose projects covering more than once sector. Among the 69 recorded hydropower projects, 61 are large-scale projects and 4 are medium-scale, and another 4 are small-scale. These projects take different forms of financing, some have been FDI projects while some others are contracting projects, and the blurred distinction has made it difficult to evaluate China's FDI in hydropower sector based on International Rivers' data. Thus instead of estimating China's FDI investment in hydropower, the project costs will be estimated. The results in table 4.25 is based on different queries implemented in the spreadsheet, to provide an approximate evaluation of the number and capacity of hydropower projects that have taken place in Africa with China's involvement. Considering that only 5 recorded projects were taking place before 2000, the spreading period of the projects could be counted as 12 years from 2000 till 2012, thus averaging at an annual hydropower project engagement scale at 0.7 GW installed capacity and approximately 3 projects per year.

Since the database has been set up based on both government and media sources, some project remains at an earlier proposed stage when the information was collected. It is noticeable that the number, installed capacity as well as project cost of the proposed and suspended projects in total are at the same level of completed and under-construction ones in total. In addition, proposed projects are the majority in comparison with suspended ones, which points to a potential increase in China's future hydropower projects if the proposed commitments will be met. This trend somehow corresponds with the second distinction that was mentioned about World Bank PPI data.

Table 4. 22 Quantity, investment value and capacity of China's dam and hydropower projects in Africa and the world (until 2012)

Project type and status		World	Africa	Africa's share
Project number	Dam total	311	89	29%
	Hydro total	255	69	27%
	CUC*	137	37	27%
	PS*	118	32	27%
Investment (Billion USD)	Hydro total	1106	35	3%
	CUC	44	17	38%
	PS	1062	18	2%
Installed capacity (GW)	Hydro total	126	25	20%
	CUC	37	9	25%
	PS	89	16	19%

Data source: International Rivers Chinese Dam in Africa database and calculations
Notes: *CUC stands for completed or under construction; **PS stands for proposed or suspended

Estimates based on AidData (2002-2012)

According to the recently published database AidData, there were 1,673 aid projects that were financially backed by Chinese sources, the total amount of which reaching 75 billion USD within the decade between 2002 and 2012. Built up on a media-based data collection approach, the dataset did provide a general image of China's growing engagement with the African continent. While the database is entitled "AidData", the financial assistant projects have a quite broad definition according to the database description, with FDI included as one type of the recorded projects. A query has been made in the database to specifically focus on the projects in the energy sector, which is to the interest of this study, namely FDI and energy. 87 projects were found relevant to the energy sector, while Table 4.23 has summarized China's involvement in the energy sector based on a total of 28 FDI projects with relatively more sufficient data and concrete project progresses.

Table 4. 23 Quantity and investment value of China's FDI in power sector from AidData database, 2002-2012

Power project type	Electricity generation related					DTG	Total
	Hydro	Thermal	Geothermal	Solar	Oil pipeline		
Project number	11	3	1	1	1	11	28
Investments (Billion USD)	4.51	0.77	0.09	n.a.	0.004	0.80	6.17

Data source: Strange *et al.* 2013 and calculations

Investment projects by SOEs in China's FDI Statistical Bulletin (2010-2011)

As the sectorial level FDI data was only started to be disclosed by MOFCOM to the public in 2011, only the project level data on China's SOEs' overseas investment in power sector from 2010 and 2011 is available. Between 2010 and 2011, among the 46 contracting projects worldwide, 3 are located in African countries, namely Zambia, DR Congo and Mozambique, and 2 of them as listed in Table 4.24 have a contract size over 0.3 billion USD.

Table 4. 24 Chinese SOEs' FDI in power sector, 2010-2011

Project	Host country	Contract value (Billion USD)	Capacity (GW)	Contract type	Contractor
Maamba thermal power plant	Zambia	0.36	0.3-0.9	EPC	China Power Investment Corp
Zongo hydropower plant, 2nd phase	DR Congo	0.38	0.15	EPC	China Power Investment Corp

Data source: CADFund, MOFCOM 2012 and World Bank PPI database
Note: *EPC stands for Engineering, procurement and construction

China-Africa Development fund as mentioned in 4.2.1 is the very first private equity (PE) fund that is specifically focusing on investing in Africa. Since the establishment of CADFund, 5 billion USD funding has been promised to be allocated towards investments in Africa. The private investment mode and the high level financial commitment of CADFund has provided Chinese investors with a new channel to finance their investments in Africa. The infrastructure sector, along with agriculture, natural resources, and industrial park projects are the four major investment fields supported by CADFund. Principally, infrastructure projects such as electric power and other power facilities which may improve local population's living standard and promote local economic development are given higher priority according to the investment philosophy of the fund.

According to CADFund (2013), 3 billion USD financing is already in place, 1.65 billion of which has already been allocated to over 60 projects in the past 5 years. Among the 60 projects, 2 power sector projects are confirmed to have taken place. The 600 MW Kafue Gorge Lower hydropower station in Zambia which was started in 2011 is one of the largest in terms of financing scale among the 60 projects that have been partially financed by the CADFund in the past 5 years, with around 2 billion funding to be raised along with the local partner Zambia Electricity Supply Corporation Limited (ZESCO). The other project is a gas-stream combined cycle power generation plant at Krone in Ghana, which was initially funded in 2007 during the first phase of the project with a capacity of 200MW. The second phase of the project was provided with more financing in 2011 to reach 560 MW installed capacity level. The investment was made by a joint venture, 40% owned by CADFund and 60% by Shenzhen Energy Investment Corporation Ltd. Both these two investment deals are in the form of BOOT (build, own, operate and transfer) within the type of Greenfield investment.

Most of the power sector projects that have been mentioned above are solely or mostly funded by the state. In recent years, private participation in infrastructure projects has also started to take place. In particular, there are several small-scale private investments in the renewable energy sector as recorded in World Bank PPI-RE database. The next section, 4.3.2, will illustrate more about China's non-hydro renewable energy investment in Africa.

China's power sector investment estimates summary

As can be seen from Fig 4.19 and Fig. 4.20, the summarized results from the three different sources share some common characteristics in terms of evolvement of project size and scale in the past decade. But considering the short period of coverage and lack of statistics to many projects, a longer-term analysis would be necessary to more precisely depict the trend of China's engagement in the power sector in Africa. Due to different sources of data collection and different extent of precision, the analyzed results from the three sources do not necessarily match in terms of quantitative indicators at certain points, such as project number and amount of investment. In addition, the International Rivers' data is specifically focusing on dams, including those for hydropower purpose, while World Bank PPI database and AidData have a broader coverage. As a result of the broad range of coverage, the project data retrieved from the latter two sources could be further divided into sub-sectors of the power industry, including hydropower, thermal and other forms of electricity generation, as well as electricity distribution and transmission, which can be used for further comparison between sub-sectors.

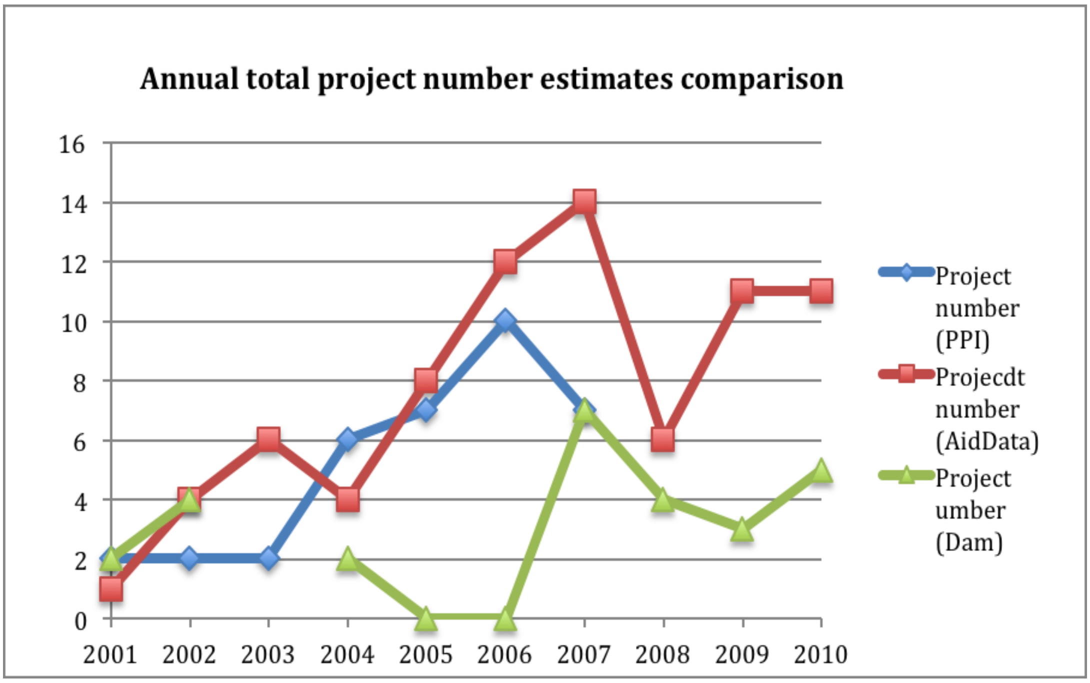


Fig. 4. 19 Annual otal project number estimates comparison among three data sources: World Bank PPI database, AidData and International Rivers, 2001-2010

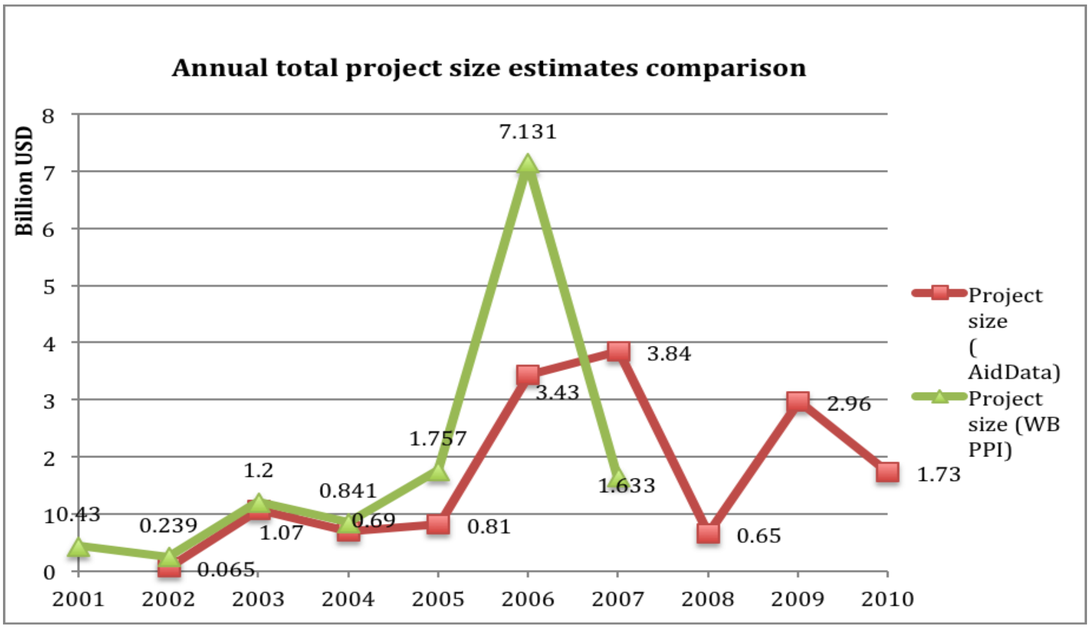


Fig. 4. 20 Annual total project size estimates comparison between two data sources: AidData and World Bank PPI database, 2001-2010

4.3.3 China's renewable energy investment in Africa

China's FDI in non-hydro renewable energy

In terms of China's renewable energy investment in Africa, a distinction needs to be made between large-scale hydropower and other renewable resources. Hydropower is already a commercially viable sector in Africa, while other renewable at scale is dependent on appropriate grid infrastructure and government schemes (WWF 2011).

Although the power sector infrastructure investments in 4.3.1 covers different aspects of the sector, including electricity generation from various sources, the investment in non-hydro renewable electricity generation was not well expose and decomposed. Based on the World Bank PPI-Renewable Energy database, this section will provide some findings on China's recent renewable energy investment in Africa. Considering that China only started to make renewable energy investment in Africa in the recent few years and that the database is newly established, the result only covers the 2011 investment that took place in sub-Saharan Africa, while it may still have future implications in comparison with China's previous energy investments.

In the PPI database specialized in renewable energy infrastructure projects with private participation, 77 projects were found in sub-Saharan Africa between 1994 and 2011, while 46 of them took place in 2011. Among the 46 projects, 3 were funded with Chinese investor's involvement. The scale and capacity of the three projects are listed in Table 4.25.

Table 4. 25 China's renewable infrastructure investment in Africa with private participation

Host country	Project value (Billion USD)	Capacity (MW)	Technology	Investment year
Tanzania	0.15	28	PV	2011
South Africa	0.18	100	Wind	2011
Zambia	1.5	600	Large hydro	2011

Data source: World Bank PPI-Renewable Energy database

On a global scale, the installed capacity potential reaches 6,418MW in the currently pipeline-stage renewable infrastructure projects (with private participation) in sub-Saharan Africa, among which large hydro is still the dominant technology component. A brief summarize of China and the world's investment on renewable technology (both non-hydro and hydro) in sub-Saharan Africa in 2010 is presented in Table 4.29.

Table 4. 26 China and world investment on renewable infrastructure in SSA (large hydro included), 2010

Type of RE technology	Total	Non-hydro	Hydro
Total investment	6418	2628	3790
China's investment	728	128	600
China's share	11%	5%	16%

Data source: World Bank PPI-Renewable Energy database and calculations

Other forms of renewable energy investments

In addition to infrastructure construction projects, China's FDI in renewable energy has also taken off in other forms such as investing in local manufacturing base. Before 2011, there were also other renewable energy investments made by Chinese companies in Africa. But as these investments are private investments and are not infrastructure projects, they are not recorded in either Chinese official statistics or World Bank PPI database, thus the information could only be sourced from investor companies' report disclosure.

While there is a lack of specific data from the official sources, some evidence could be spotted from the AidData database. In the query results for China's power sector related investment between 2002 and 2012, four entries that are non-infrastructure investments are listed in Table 4.30. There are also other up to ten entries related to renewable energy manufacturing, but these four are the only ones with recorded agreement and concrete investment deal, while others are in the form of MOUs between potential partners or expressed intention for investment.

Table 4. 27 Project information of China's renewable manufacturing investment in Africa

Year	Project value (Billion USD)	Technology/type	Investor	Recipient country
2007	0.14	Solar/Manufacturing	Tianpu Xianxing	Kenya
2010	0.435	Solar/Manufacturing	Yingli	South Africa
2010	0.035	Solar/Solar panel assembly&production plant	ZTE	Congo Rep
2011	12.56	Wind/Wind turbine manufacturing	Ming Yang	South Africa

Data source: Strange *et al*. 2013 and calculations

The $12.56 billion deal on wind turbine manufacturing made by Ming Yang Wind Power Group, a top Chinese wind turbine manufacturer, is by far one of China's largest scale renewable energy manufacturing investments in Africa. As a result, 2000 wind turbines are expected to be manufactured locally and erected close to the wind farm, with Ming Yang as the major supplier. In addition, another Chinese wind turbine manufacturer, Longyuan, has also announced plans to build manufacturing facilities in South Africa as recorded in AidData, though no concrete investment has been made so far.

Another earlier practice is Chinese PV manufacturer Beijing Tianpu Xianxing Enterprise's $0.1 billion USD investment in building up Kenya's first PV manufacturing plant in Nairobi with a local partner enterprise in 2007 (Economy 2010; Disenyana 2009), though it turned out to be a failed case as the plant was shut down after two years due to lack of mobilized local demand. However, it can be seen that more solar manufacturers are entering the market despite of this earlier failure. In 2010, Chinese solar manufacturer Yingli became the first Chinese as well as renewable energy enterprise sponsor of South Africa World Cup, which is followed by the 0.435 billion solar manufacturing investment deal that was signed not long after the World Cup.

Although the quantity and total volume of non-hydro renewable investments,, both infrastructure and manufacturing, are still not comparable to large hydro investments made by Chinese companies in history, the emerging trend and potential is worth a longer-term observation.

4.4 Discussions

In the previous three sections, the projections based on different scenarios of Africa's energy development have laid out the technical and financial needs of the continent in order to reach sustainable energy development goals. A general image of China's historical energy investment in Africa has also been presented based on data from official and non-official, international and Chinese sources. This section would compare between China's energy investment potential on the continent and Africa's energy development needs and come up with implications on China's role in financing Africa's modern energy development.

4.4.1 Estimates and projections on China's future energy investment in Africa

Brief summary of current investment

Foster *et al*. (2009) claimed that China's investment made by the end of 2007 were already expected to increase the total available hydropower generation capacity in SSA by 30%. To some extent, China's strong engagement in the hydropower infrastructure sector has been confirmed by the results on China's energy investment in section 4.3. Hydropower is by far still the most important component of China's engagement with improving Africa's modern energy access.

While 4.3 has made a separate estimates of China's current investment in non-hydo and hydro, infrastructure and manufacturing projects, it would also be important to have a general image of China's total energy investment portfolio in Africa. While recognizing the defect of insufficient data, especially on private investment, a simple aggregate of the already recognized investments between 2010 and 2011 is presented as in Table 4.28 to provide a rough estimate of China's recent endeavor in energy investment in Africa.

Although China is still playing a limited role in the non-hydro renewable energy sector in sub-Saharan Africa, it can be seen from the aggregation of the renewable energy investments presented in section 4.3.3 that both infrastructure and manufacturing investment are starting to take off in Africa, and the scale is already impressive considering that non-hydro renewable investments, especially private ones are not in huge scale as state backed ones.

Table 4. 28 Capacity and project value of China's energy investment in Africa, 2010-2011

2010-2011	Renewable			Thermal plant
	Hydro	Non-hydro		
	Infrastructure	Infrastructure	Manufacturing	
Project value (Billion USD)	1.88	0.33	0.47+(12.56)	0.36
Capacity (GW)	6.15	0.128	-	0.3

Data source: MOFCOM, Strange et al. 2013, World Bank PPI-RE database, and own calculations

It is worth noting that what drives the non-hydro manufacturing project value potentially high, is the $12.56 MingYang deal, the funding of which is expected to be raised in a few years. The investment is involved with South Africa's Lesotho Highlands Power project, which is expected to reach a total of 6GW of wind power capacity with 4GW of pumped-storage hydropower capacity (Ming Yang 2011). Thus this manufacturing deal is also contributing indirectly contributing to the increase of local renewable installed capacity.

Another estimate of China's power sector state-backed investment volume

China's power sector OFDI flow and the total OFDI flow have shown correlated changing patterns in the past decade, while both of them have been volatile. In the recent three years after the 2008-2009 financial crisis, China's power sector FDI has shown more steady growth trend. According to the compounded growth rate result, the power sector is showing a stronger growing trend than China's total OFDI. In 2011, China's power sector OFDI flow has reached a historical highest level of $1.01 billion, representing 2.52% share of China's total OFDI flow, which is also a highest level of power sector's share in China's total OFDI in the past decade.

In the 12th Five Year Development Plan (2010), MOFCOM has made the promise of achieving a 17% annual growth rate in China's total OFDI flow and reaching $150 billion OFDI flow volume by 2015. While there is no specific target set for the power sector, considering the currently stable annual growth rate of above 50%, China's power sector OFDI can be expected to reach $5 billion level by 2015, and since the estimate is based on MOFCOM's assumption, it mostly refers to state backed investments.

Future trend in terms of investment type and investor components

It has been claimed by MOFCOM (2012) that China's increasing FDI in the energy sector is having a positive impact on China's export of electric equipment and technologies, and would increase encourage manufacturing companies to further invest in Africa, thus empowering local electric manufacturing. Likewise, China's engagement in renewable infrastructure projects is also expected to move forward China's renewable energy equipment exports to Africa, especially considering the overloaded supply situation in the current domestic market. However, as mentioned by WWF (2011), in order to complement and assist with China's renewable energy investment in Africa, localized manufacturing would be a more effective and efficient solution to empower local industries and realize the mutual benefits. As implied by the WWF report on China's role in renewable energy development in Africa and can be seen from the case of MingYang wind turbine deal, a combination of investment in infrastructure and renewable equipment manufacturing would have synergic impact on Africa's long-term clean energy development.

Another trend in China's energy investment in Africa is the increase of BOOT type of Greenfield investment in China's recent investments, namely the Kaefue Gorge Lower hydropower project and the Ghana thermal plant financed by CADFund. While traditionally SOEs have been the major player in energy investment, the involvement of CADF fund has leveraged the private share of the total investment and is expected to bring in more private participation in China's future energy investment. With the financial and expertise background of CADFund, the existing investments are expected to bring in more private investors in Africa's energy sector. The public-private infrastructure financing mode is also expected to be adopted by more FDI projects in the future.

4.4.2 China's role in financing Africa's energy needs

The transition towards a modern energy system requires increasing investment in technology and infrastructure. As mentioned in WEO (2010) and confirmed in Chapter 4, Chinese companies' overseas non-fossil energy investments are mainly focusing on hydropower projects, especially large scale ones. Other types of renewable energy projects have started to take up, and have a strong potential, but the investment volume is limited at the moment in comparison with hydropower investments, which are mostly backed by state financing. There are a few non-hydro investment cases in wind farms, solar plants, as well as wind and solar panel equipment manufacturing, the size and capacity of which are diverse.

Referring back to section 4.1, where Africa's different energy development scenarios were depicted in comparison with the business-as-usual scenario and the investment needs were estimated, one major transformation that turns out from the Baseline to the GEA-Mix scenario is the dramatic increase of renewable energy in the electricity generation mix as shown in Table 4.29. In GEA climate scenarios, by 2030, half of the electricity generated in Africa is expected to come from renewables, with solar and wind accounting for about 60%. Such a transformation of the electricity generation mix is expected to meet Africa's sustainable energy development goals, including access to modern energy as well as enhancing energy diversity and security. The equivalent investment needs are huge, with the total supply side investment at an equivalent level of $61 billion per year, which accounts for more than 90% of the total investment in energy in Africa until 2030.

Table 4. 29 GEA-Mix Scenario electricity mix and investment needs summary

Year	Electricity generation (Billion kWh/yr)						Non fossil-electricity investment needs (Billion US$)
	Fossil fuel	Renewable					
		Solar	Wind	Hydro	Geothermal	Biomass	
2010	677	1.39	1.67	83.96	1.39	0	0.78
2030	616	128	106.75	227.83	1.13	0.89	33.77

Data source: GEA Scenario database and own calculations

To link China's current investment estimates with Africa's sustainable energy needs, a further estimates is presented in Table 4., comparing China's existing infrastructure investment (renewable manufacturing not included) with Africa's investment needs.

Table 4. 30 Comparison between China's current energy investment and Africa's sustainable energy investment needs

		Non-fossil electricity		TDG	Total	The share of China's investment in Africa's total needs
		Hydro	Non-hydro			
China's current investment (bln USD/year)		0.94-3.0	0.4	0.06	1.4-3.5	-
GEA-Mix supply-side investment needs (bln USD/year)	2010	0.78		6.38	7.14	≈20%-50%
	2030	33.77		21.7	55.47	≈50%(assuming 10% annual growth rate)

Data source: Chapter 4.1-4.3 results and own calculations

It is worth noting that China's current investment level is already accounting for around 20% of Africa's total energy investment need at present. While the upper level of the estimate takes into account the postponed or suspended projects, if these projects are to be implemented in the near future, China's contribution could account for more than 50% of the sustainable energy investment needs in Africa. In addition, if taking China's FDI, especially power sector FDI's fast growth in recent few years, if following the growth trend, even at the very conservative estimate of 10% growth per year, China's energy sector investment in Africa is expected to be capable of supporting at least 40%-50% of Africa's energy investment needs by 2030.

In addition, the estimate above is focusing on the infrastructure aspect. Considering the growth of Chinese renewable manufactures' involvement in Africa, and the synergic effect this would have on infrastructure development, China's role in Africa's future energy development could be much more substantial.

Although numbers may not necessarily tell about the quality behind the investment projects, or more particular, whether the investment goes to the most needed fields, a closer look at China's increasing focusing investment fields would give a positive answer. In terms of focusing sectors, China's recent growth in wind turbine and solar manufacturing as well as wind and solar infrastructure investment to some extent is showing its pioneering role and aligns with GEA-Mix scenario's sustainable energy development path design, with a projected dominant role of these two renewable resources. Since GEA-Mix has its advantage of adapting to regional characteristics, it can be expected that solar and wind are the two most economic and viable renewable sources for electricity generation between 2010-2030 stage, and China with its existing successful experiences in solar and wind manufacturing, could contribute even more than the estimated level.

What has also added strength to Chinese investors' potential is the high-level official commitment from China's side. At the 2009 China-Africa Cooperation Forum, Chinese premier Wen Jiabao announced that China would carry out 100 renewable energy projects (excluding large hydropower) in African countries. This commitment, in combination with the financial and expertise support of CADFund, is providing an important catalyst for

Chinese companies' to make more substantial moves on energy investments in Africa and further synergize with the continent's sustainable energy development.

5. Conclusions

This study aimed at examining China's role in financing Africa's sustainable energy development. Based on an analysis of the scenarios by GEA, WEO and AfDB, it has been estimated that in order to reach a sustainable energy future with modern energy access and guaranteed energy security, the continent is faced with a huge amount of energy investment needs, equivalent to $40-60 billion per year by 2030, the majority of which should occur on the supply side.

Under the climate policy scenario, the projected supply-side investment in non-fossil electricity generation and CCS technologies, which is equivalent to $33.8 billion per year, are expected to equip the continent with an electricity generation system with more than 50% powered by renewable energy, especially wind and solar technology and realize the objectives of modern energy access and energy security benefits on a more reliable and secure system.

The summarized results on China's past decade's energy investment projects in Africa have confirmed the claim that "Chinese finance is on a scale large enough to make a material contribution toward meeting Africa's vast infrastructure needs" (Foster *et al.* 2008). Moreover, the thesis makes clear that this material contribution can be as much as one-half if not more. The summarized data on existing projects also imply that most of the contribution so far, as also mentioned in existing literature, are in hydropower. However, the recent few years' trend has shed light on China's potentially stronger growth on non-hydro investments in renewable energy, in terms of both infrastructure and manufacturing projects.

In comparison with the projected sustainable energy scenario, namely GEA-Mix Scenario, it has also been discovered that China's recent increase in solar and wind renewable investments does align with the projected path for Africa's sustainable energy development, where renewable energy is contributing to half of its electricity mix and a substantial increase in the share of wind and solar is expected. It has been estimated that China is contributing to around 20% of Africa's current energy development needs, while in the near future, with the high level official commitments and the ambitious renewable manufacturers at the table, this share is expected to have a substantial increase. At the same time, China is expected to share its experience especially in wind and solar sectors, to provide both technical and financial support in the process of financing Africa's energy future.

Fulfillment of these optimistic projections depends on a number of assumptions. First, Chinese investors should be able to change their preferences for very large hydropower projects for comparatively smaller wind, solar and bioenergy developments. Secondly, the geographic base of China's investment should broaden from the relatively few (mostly oil- and minerals-rich) countries today to a larger number of countries including those with most acute energy needs. Third, China's investment should be not only on the supply side, but also cover transmission and distribution (which according to all projections may require similarly large amounts of investments). Fourth, China's commercial investment should be aligned with loan and aid strategies, which are arguably better instruments to provide sustainable energy access. Finally, host countries in Africa will need to improve their regulatory regimes for receiving growing and diverse energy investment from China.

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