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Renewable energy policy as an enabler of fossil fuel subsidy reform? Applying a socio-technical perspective to the cases of South Africa and Tunisia

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Abstract:

Fossil fuel subsidies are a key barrier for economic development and climate change mitigation. While the plunge in international fuel prices has increased the political will to introduce fossil fuel subsidy reforms, recently introduced reforms may risk backsliding when fuel prices rebound – particularly if they fail to address the underlying mechanisms that create demand for low fossil fuel prices. Extant literature has mostly focused on the consequences of fossil fuel subsidies, including their economic or environmental impact, and the social contract that make their reform difficult. In this paper, we complement the extant literature with a socio-technical perspective of fossil fuel subsidies to explore the systemic mechanisms that often keep subsidies in place and how these mechanisms can be weakened. Specifically, in case studies of the electricity sectors in South Africa and Tunisia, we trace the socio-technical foundations of their fossil fuel subsidy regimes and the potential of renewable energy policy in disrupting this regime. We discuss the relevance of our results for national policymakers wishing to implement and international actors wishing to support fossil fuel subsidy reform. In particular, we highlight that the socio-technical perspective of fossil fuel subsidies offers new intervention points for subsidy reform and that policy designs and assistance should strengthen technologies and actors that are most likely to destabilize the fossil fuel subsidy regime.

Keywords: Lock-in, Fossil fuel regime, Climate change, Political economy, Policy change

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The [Energy Politics Group \(EPG\)](#) within the [Department of Humanities, Social, and Political Sciences](#) of [ETH Zurich](#) investigates questions related to the governance of technological change in the energy sector.

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1 Introduction

Fossil fuel subsidies are a major economic distortion. They often drain state budgets, encourage greenhouse gas emissions and, due to their typically poor targeting, slow economic development (IEA, 2011). Fossil fuel consumption subsidies alone totaled an estimated 325 billion USD in 2015 (IEA, 2016), dwarfing the volume of annual international climate finance of 100 billion USD pledged under the United Nations Climate Agreements (UNFCCC, 2009), and the 131.1 billion USD of official development aid from OECD donating countries in 2015 (OECD, 2016). While the 2015 fossil fuel subsidy estimate marks a decrease from the 2014 estimate of around 500 billion USD (IEA, 2015), this decrease was largely driven by the drop in global fuel prices since late 2014, rather than proactive fossil fuel subsidy reform (FFSR). Low international fuel prices naturally narrow the gap between subsidized and international fuel prices. This convergence inherently reduces national fossil fuel subsidy bills and also provides a window of opportunity for policymakers to remove fossil fuel price controls with a lower impact on end user prices (IEA, 2016; Kojima, 2016). While these low international prices help suppress the political controversy that typically accompanies FFSR, if the recently introduced reforms fail to address the underlying mechanisms that create demand for low fossil fuel prices, they may lack stickiness when international fuel prices rise. In the past, FFSR policies were often reversed in the face of public opposition to high energy prices (Lockwood, 2015; Rentschler and Bazilian, 2016).

In this paper, we complement the dominant economic, political and energy planning perspectives of fossil fuel subsidies with a *socio-technical* perspective. From this perspective, fossil fuel subsidies represent more than simply an inefficient allocation of funds: they are locked-in by an energy system dominated by fossil fuel-based technologies and are reinforced by positive economic, institutional, and political feedbacks. However, the emergence of new technologies, such as renewable energy technologies, that challenge the dominance of the incumbent ones can lead to structural changes within the energy sector (Moe, 2010). We therefore explore whether renewable energy policies, by creating and nurturing positive

feedbacks for fossil free energy technologies, can undermine and eventually disrupt the locked-in fossil fuel subsidy system.

In section 2 we review three perspectives of FFSR and add our socio-technical perspective to the debate. After describing our case selection and methods (section 3), in section 4 we apply this perspective to two case studies of the electricity sectors in South Africa and Tunisia. In each case, we show how centralized fossil fuel technologies co-evolved with and helped *lock-in* fossil fuel subsidies and how renewable energy technologies can act as *seeds of disruption* to destabilize the current subsidy regime. The case studies entail estimates of the dynamic incremental generation cost of renewables over the subsidized and unsubsidized baseline. The incremental cost estimates help to understand the competitiveness of renewables, how this competitiveness is affected by fossil fuel subsidies. They also provide an indication of the cost of renewable energy support. The dynamics of the renewable energy generation cost reflect the learning that stems from the economic feedbacks. In section 5, we integrate the three extant and the new socio-technical perspective in one framework, discussing, how this integrated approach provides new intervention points for subsidy reform. We conclude by discussing implications for national policymakers and international actors.

2 Review of perspectives on fossil fuel subsidies and their reform

In this section, we trace three historical perspectives of fossil fuel subsidies – the theoretical *economic* foundation, a *political economy* approach, and an *energy planning* perspective – and add a *socio-technical* perspective to the debate. Fossil fuel subsidies often originate as a mechanism to foster economic development (see panel (a) in Figure 1), for example by promoting industrialization or access to affordable energy (Rentschler and Bazilian, 2016). However, studies have shown these subsidies create inefficiencies by over-incentivizing fossil fuel consumption, resulting in environmental externalities (Burniaux and Chateau, 2014; Schwanitz et al., 2014), greater economic inequality (Arze del Granado et al., 2012), and ultimately a subsistence on continued fossil fuel subsidy provision. From a classic *economic* perspective, FFSR is then a ‘win-win’ policy resulting in improved economic efficiency and

environmental benefits. Many studies employing computable equilibrium models have quantified the large potential gains of FFSR (Ellis, 2010); however, these studies do not capture the implementation challenges involved in reforming fossil fuel subsidies (Jenkins, 2014).

Alongside this economic literature has grown a body of scholars analyzing the *political economy* of fossil fuel subsidies and their reform, particularly from a public choice perspective (Victor, 2009) (see panel (b) in Figure 1). Political economy analyses of FFSR offer an extension to economic models by integrating the role of populist incentives for subsidy provision. To date, these analyses have largely focused on the distributional impact of fossil fuel subsidies and their reform to identifiable coalitions, and are rooted in a logic of rent-seeking (for a critique see Lockwood 2015). The resulting reform space typically comprises mechanisms that attempt to redistribute the fiscal savings from the subsidy reductions to compensate opposition stakeholder groups perceived as particularly powerful. Given that these groups often prevent open discussion of FFSR in normal times, fossil fuel subsidies usually only arise as an issue if public budget imbalances lead to pressure from external creditors to embark on fiscal austerity (de Moor, 2001; Koplow, 2009) – as evidenced by the International Monetary Fund’s (IMF) extensive involvement in FFSR policies and debates. However, in a situation of severe fiscal imbalance, developing country policymakers attempting to reform subsidies often lack the financial and institutional capacity to credibly implement these compensation schemes, as well as manage the distributional impact of subsidy removal (Victor, 2009). As a result, reforms are often short-lived as governments backslide under mounting political and social opposition (IEA, 2015).

Literature on FFSR has also started to consider the impact of fossil fuel subsidies in *energy planning* and investments (see panel (c) in Figure 1). In particular, fossil fuel subsidies are recognized as a barrier to the diffusion of low-carbon technological substitutes such as renewable energy technologies (Bridle and Kitson, 2014; Merrill et al., 2015; Schmidt et al., 2012). In the electricity sector, for example, fossil fuel subsidies crowd out investments in electricity infrastructure or diversification (Mcrae, 2013), distort investment decisions (Bridle and Kitson, 2014), create barriers to entry for renewable energy developers

and foment institutional deficiencies in the electricity sector (Bazilian and Onyeji, 2012) – all of which give conventional fossil fuel-based generation technologies an incumbent advantage. However, focus has remained on examining how fossil fuel subsidies create a lock-out of renewable energy technologies and has yet to fully consider the relationship between technological change and the lock-in of fossil fuel subsidies.

Figure 1: Three dominant perspectives of fossil fuel subsidies: (a) classic economic theory, (b) public choice perspective, and (c) energy planning.

In this paper, we argue that a *socio-technical* perspective of fossil fuel subsidies can complement these perspectives and offer new insights on levers for subsidy reform. In this perspective, energy technologies are not simply hardware that provide services such as electricity or transport (Nygaard and Hansen, 2015; Tushman and Rosenkopf, 1992). Instead, technologies shape and are shaped by the societies in which they evolve – economically, institutionally and politically (Arthur, 2009; Berkhout, 2002; Rip and Kemp, 1998; Unruh, 2000). As a dominant technology emerges, such as centralized fossil fuel technology, it can create positive feedbacks. These feedbacks can be of economic nature, creating economic path dependency and eventually technological lock-in. Arthur (1989) has identified four positive feedback mechanisms: technological learning (expressed e.g. in experience curves), sunk costs, network effects, and shared expectations. Other authors have focused more on positive institutional feedbacks that alter norms, policies, and regulations (Geels, 2004, 2002; Unruh, 2000). Institutional feedbacks are particularly important in the energy sector, as it typically requires a strong role of regulatory and other institutions

(e.g., due to the presence of natural monopolies) (Verbong and Geels, 2007). Importantly, feedbacks from technical progress also often affect underlying politics, by modifying political costs and options (Jordan and Matt, 2014). Thereby they can create or augment existing political path-dependencies (Pierson, 2000). These economic, institutional and political feedbacks can thus create ‘techno-institutional complexes’ (Unruh, 2000) or ‘regimes’ (Geels, 2002), which are economically, institutionally, and politically entrenched and thus difficult to reconfigure (Fouquet, 2016).

. We argue that fossil fuel subsidies can also be viewed as the result of a path-dependent process involving feedbacks between economic actors, institutions, policymakers and fossil fuel-based technological change (de Moor, 2001; Unruh, 2000). Coming from this socio-technical perspective, we seek to explore the economic, institutional and political path dependencies that led to today’s subsidies and whether disrupting these technology foundations can be an effective strategy to support reform.

3 Methods and case selection

We apply a mixed methods approach to case studies of the South African and Tunisian electricity sectors to understand the role of energy technologies in the political economy of fossil fuel subsidies and their reform. Specifically, we first trace the technological basis of the current fossil fuel subsidy regime, exploring how fossil fuel subsidies historically developed with and became *locked-in* by the national energy system, as well as the emerging low-carbon technological changes, or “*seeds of disruption*,” that can destabilize this regime.

We then develop a quantitative techno-economic model to explore the cost of supporting this process of fossil fuel subsidy disruption through renewable energy policy. Specifically, we calculate the country-specific marginal generation cost of the operating and new-build baseline technologies over a 10-year period under two different assumptions: the first assumes subsidized fuel prices remain constant in real terms and the second assumes unsubsidized prices for fuel. Note that the assumption of constant subsidized fuel prices may be extreme as in reality price contracts may increase in the future. We then compare these costs to the cost of wind and solar PV generation. For South Africa, we compared historical

costs of renewable generation, as these data were available from 2011 to 2014. For Tunisia, we modelled the levelized cost of wind and solar PV, as the utility-scale renewable energy market in Tunisia is still immature. The dynamic cost of renewable energy capture the economic feedbacks between renewable energy deployment and technological change through cost reductions due to local and global learning (Huenteler et al., 2016). By comparing these costs to the baseline, we can estimate the impact these changes have on the cost-competitiveness of the renewable energy technologies compared to fossil fuel-based generation over time (which is relevant for the economic and the energy planning perspective). The incremental cost (i.e. the cost differential between renewable and fossil fuel based technologies) also indicates which economic support level renewable energies require, indicating the costs of planting the seeds of disruption (which is relevant for the economic and the socio-technical perspective). As such, the quantitative analysis helps integrating the different perspectives on fossil fuel subsidies. The modelling case assumes that wind or solar PV comprise 10% of electricity generation in Tunisia after 10 years of deployment. Details of the model can be found in Appendix A and key modelling assumptions and data can be found in Appendix B.

The case studies of South Africa and Tunisia were chosen due to the structure of their electricity systems. In both countries, electricity supply is subsidized and undiversified. Also, both are characterized by a vertically integrated monopolistic electric utility largely reliant on one fossil fuel type for power generation. Their reliance on a single fuel allows us to more easily trace the historic foundations of their fossil fuel subsidy system. At the same time, these countries have high potential for wind and solar energy and support for the deployment of these technologies is gaining momentum. Both countries are also well integrated into world trade and have harbor infrastructures, meaning renewable energy components (including bulky components of wind turbines) can be easily imported. This aspect is important, as the availability of renewable technologies, which were originally developed in other markets, is a critical condition for the logic of ‘planting seeds’. Beyond these similarities, these countries were also chosen to reflect variation along two dimensions: their trade balance for fossil fuels and baseline fuel type. Trade balance, or whether a country is a net importer or exporter of the fossil fuels it uses to generate electricity,

influences the mechanism of subsidization as well as the national perception of subsidies (Victor, 2009).

The second dimension, baseline fuel type, largely drives baseline generation and fossil fuel subsidy costs as well as the fuels' embeddedness within the local economy. Additionally, South Africa has a more advanced renewable energy policy and has experienced substantial investments into wind and solar PV in recent years.

4 Results

In this section, we present the results of the case studies. Section 4.1 describes the emergence of public support for coal-based electricity in South Africa (section 4.1.1), and the renewable energy niche developing under its renewable energy procurement program (section 4.1.2). We discuss the Tunisian case in section 4.2, tracing the technical roots of natural gas and electricity subsidies (section 4.2.1) and the potential for renewable based electricity (section 4.2.2).

4.1 South Africa

4.1.1 The lock-in of fossil fuel subsidies

South Africa's abundance of coal has engendered an economy dependent on low-cost electricity, a political elite dominated by powerful mining interests and an energy system based on inefficient coal-based technology. South Africa is both one of the largest producers and consumers of coal worldwide; historically, it has exported its higher grade coal and utilized lower grade coal for domestic energy production (IEA, 2014a). The infrastructure built around South Africa's existing coal mines has played a key role in shaping both the export and domestic coal industries.

Most coal designated for export is transported to the privately owned Richard's Bay Coal Terminal via public railway, itself an indirect subsidy to the coal industry. Export rights at Richard's Bay are allocated according to shareholders, which has reinforced the market power of a select few coal production companies (Eberhard, 2011). From the 1970's until 1991, the issuance of export permits was conditional on mining companies agreeing to supply Eskom, the vertically integrated publically owned electric utility, with low-cost coal (Burton and Winkler, 2014). Public involvement both in the export coal industry as

well as the energy sector marks the beginning of a complex intertwining of energy and mining interests in South Africa (Fine and Rustonjee, 1996).

Coal currently accounts for over 90% of South Africa's electricity supply (Altieri et al., 2016). The boom in coal capacity was most pronounced in the 1970's and 1980's. During this period, Eskom expanded coal capacity from 6500 MW in 1969 to 25,000 MW by 1990 (Burton and Winkler, 2014). Many of these power plants are mine-mouth plants supplied coal via conveyor belts directly from nearby mines. Eskom procures coal predominantly through long-term 'cost-plus' or 'fixed price' contracts with mining companies and in some cases even covers a share of the capital and operating costs of the supplying colliery (Eberhard, 2011). In these contracts, Eskom does not pay the market price for coal; historically domestic prices were as much as five times lower than free on board prices (IEA, 2014a). As themselves some of Eskom's biggest electricity customers, coal mining companies also had an incentive to keep domestic electricity prices, and thus their own production costs, low. By cross-subsidizing between the export market – which they controlled through export allocations at Richard's Bay – and the domestic market, these companies were able to recover their capital investments while supplying Eskom with cheap coal (Eberhard, 2011). Furthermore, the close relationship between Eskom and mining companies proved mutually beneficial for two reasons (Burton and Winkler, 2014). Firstly, with the development of coal washing technology, coal producers could export high-grade washed coal and sell the middling, or byproduct of the process, to Eskom. Therefore, Eskom's willingness to utilize middling presented producers with an otherwise non-existent market for this lower-grade coal. Secondly, limited railway capacity imposes a constraint on export volumes; therefore the presence of a dependable and accessible domestic market has been beneficial for producers. Eskom too, has benefited from this capacity constraint as it kept domestic coal prices low, even when export prices were high.

This system of privileged access to coal contracts and the rapid build-out of Eskom-owned power plants helped solidify Eskom's dominance in the electricity market. Eskom effectively has a monopoly in the electricity sector, producing 95% of South Africa's electricity (Baker et al., 2014). It has resisted previous attempts at unbundling and increasing competition significantly in generation by lobbying government

and citing their precedent of low-cost electricity provision as a rationale for maintaining market dominance (Eberhard, 2007). Its bargaining power and privileged access to policymaking and planning ministries are also evident by its involvement in the technical task team of South Africa's 2010 Integrated Resource Planning (IRP) process. This IRP, which outlined South Africa's electricity investment needs until 2030, had been criticized for allocating excessive coal capacity additions (Baker et al., 2014).

As a result of an over-building of generation capacity in the 1970's and 1980's and low-cost contracts for coal, South Africa has enjoyed some of the lowest electricity tariffs in the world (Baker et al., 2014). These electricity tariffs, which are set by the national energy regulator, NERSA, did not keep track with inflation, leading to end user prices below Eskom's cost recovery (IEA, 2014b). As a result of both of these factors, Eskom has invested little in the electricity sector since the 1980's: most of the coal plants operating now utilize subcritical technology with low efficiencies and availabilities (IEA, 2014a). Poor maintenance of the electricity system led to an escalation of rolling blackouts in 2008 and again in 2014 and 2015. In the wake of the electricity crisis in 2008, in which Eskom faced both a financing crisis and capacity shortage, NERSA approved significant electricity tariff increases (Baker et al., 2014). However, further requests for tariff increases have been only partially approved, as a legacy of cheap electricity forms the structural basis for South Africa's economy and, in turn, has entrenched powerful and connected political interests in these energy-intensive sectors (Fine and Rustonjee, 1996; Rafey and Sovacool, 2011). Therefore, despite the seeming inevitable end of the cheap coal era and the need to invest in the electricity system, there is political pressure to limit further price increases (IEA, 2014a). With further deterioration of Eskom's financial situation, the government injected 23 billion rand (1.7 billion USD) into Eskom in 2016 (Kojima, 2016).

4.1.2 The seeds of disruption

For South Africa, the largest cost of its coal and electricity subsidy regime lies not in the direct cost of the subsidies themselves, but in the intrinsic cost to its energy sector and national economy. However, Eskom's current crisis can also strategically be framed as an opportunity to transition to a greener and more secure energy economy. Since 2011, South Africa has experienced a surge in renewable energy

investment due to the success of its Renewable Energy Independent Power Producers Procurement Programme (REIPPPP) (Baker, 2015). In just three years, the scheme successfully channeled over 14 billion USD of private sector investment into grid-connected renewable energy technologies (Eberhard et al., 2014). As this niche in the electricity sector has gathered momentum, it has already begun to disrupt some of the coal-dominated structures in its subsidy regime.

Firstly, the setting up of the REIPPPP has altered the prevailing market dynamics within the electricity sector. Most importantly, it has increased competition and diversity into the traditionally Eskom- and coal-dominated electricity market. The REIPPPP underwent several changes during the policy design process, most notably transitioning from a feed-in tariff (FiT) to a competitive bidding system. Under the FiT scheme, NERSA would have been responsible for setting tariffs for renewable energy projects. Instead, the competitive bidding process shifted price setting away from centralized control. The decentralization of price setting, combined with a strategy of procuring renewable energy capacity in multiple bidding rounds, has enabled renewable energy tariffs to drop significantly with each bidding round. As seen in Figure 2, round four bids for wind and solar PV are even competitive with new build coal power plants when market prices of coal are considered. Note that REIPPPP bids are fully indexed with inflation of the Rand and are presented in 2016 USD using an exchange rate of 14.71 ZAR₂₀₁₆ per USD₂₀₁₆ (OECD, 2017). Furthermore, the entry of independent power producers (IPPs) breaks Eskom's market power and has provided an opportunity to rapidly roll out and legally connect privately owned generating capacity (Eberhard et al., 2014); large power projects owned by Eskom typically have taken years before commissioning. These developments undermine the political and bargaining power Eskom has previously enjoyed, as it can no longer claim to be the most competent provider of low-cost electricity for the population.

Additionally, it has fostered an emerging local industry poised to benefit from increased renewable energy growth. Under the REIPPPP, bids are evaluated on both price and socio-economic criteria such as job creation, rural development, and black enterprise development (Walwyn and Brent, 2014). These local

content criteria helped in generating political support for the REIPPPP (Hochstetler, 2015) and could also prove crucial to undermining incumbent industries. For example, at present, official unemployment stands at 26.5% (Stats SA, 2017) and employment and wages in the coal sector have been declining (Eberhard, 2011). The projects under the REIPPPP have promised to create both temporary and permanent jobs (Eberhard et al., 2014) and, while the extent of actual job creation is difficult to estimate, several local wind tower manufacturing facilities and solar PV assembly plants have been built or are under development (Baker, 2016), thus sinking capital into and increasing interests in a domestic RET industry.

Figure 2: Costs of electricity generation in South Africa based on REIPPPP bids (Republic of South Africa Department of Energy, 2015) and modelled costs of coal fired generation.

Finally, as mentioned previously, wind and solar PV have realized significant cost reductions due to technological learning at both a local and global level. As shown in Figure 2, renewable energy technologies are reaching cost competitiveness with unsubsidized (and in the case of Wind even highly subsidized) new-build coal power plants. This development occurs at a crucial time in South Africa: many of Eskom's cheap long-term coal contracts are expiring and it increasingly needs to turn to more

expensive sources of domestic coal as mines situated near existing mine mouth plants deplete (Durbach et al., 2017). As attention shifts to new coalfields in the Waterberg region, public support for coal has faltered. The state-owned railway has delayed commitment to building additional capacity to transport coal from these new fields for the domestic market while, at the same time, Eskom has been unable to politically and economically justify investing capital in coal mines as it did in the past (African Mining Intelligence, 2016; Energy Monitor Worldwide, 2016). The cross-subsidization model between export and domestic industries is becoming less attractive to private mining interests as well, given that, despite decreasing overall coal demands, demand for low-grade coal has increased in Asian markets (Durbach et al., 2017). Although South Africa's latest IRP has outlined a significant role for coal (and nuclear) in the future, these projections have been met with pushback from stakeholders who have used the recent REIPPPP bids to support their argument that the least-cost electricity system is one primarily based on renewable sources of energy.

Renewable energy projects still face significant challenges such as integration into an undercapitalized and Eskom-controlled grid, a perception that it is inadequate to provide baseload power, a lack of clarity in the local content requirements and difficulties building the technological capabilities needed for localizing low-carbon industries (Baker and Sovacool, 2017). However, renewable energy deployment has set in motion dynamics that can potentially break the lock-in of directly and indirectly subsidized coal-powered generation: undermining the economic rationale for centralized coal-fired power, eroding the market power of Eskom and other energy-intensive local industries, and building political support for a greener growth trajectory.

4.2 Tunisia

4.2.1 The lock-in of fossil fuel subsidies

Just as South Africa's electricity system is heavily reliant on coal, Tunisia relies almost exclusively on natural gas for electricity production. The state-owned electric and gas utility, Société Tunisienne d'Electricité et du Gaz (STEG), supplies the majority of domestic electricity needs and, through this service, has served as a strategic social, political and economic tool in Tunisian society. In particular,

subsidized energy prices have been a cornerstone of Tunisia's development strategy (The World Bank Group, 2015). Electricity is subsidized both directly, through tariffs set below STEG's cost of production, and indirectly, through preferential prices for natural gas (Belet Cessac, 2014; The World Bank Group, 2014a). However, as these subsidies have grown increasingly entrenched in the social contract between the state and the population, they no longer function solely as a means of social protection, but also as the inevitable cost of political stability (Blatter and Buzzell, 2013).

Underlying Tunisia's reliance on subsidies in the electricity sector is its reliance on natural gas for electricity generation. Prior to the 1970's, the Tunisian energy sector was petroleum-based; however after the oil shocks of the 1970's, and with domestic oil production in decline and domestic natural gas exploitation rising, natural gas use rapidly expanded (Rekik et al., 2014). Electricity production largely drove the growth of the natural gas industry as it proved an attractive substitute for oil: The national government viewed domestic natural gas exploitation as a means to improve the trade balance and, for STEG, switching from oil-based generation to natural gas lowered fuel costs and, as investment costs and commissioning times of natural gas power plants are low, allowed STEG to rapidly expand generation capacity to meet rising energy demands (Rekik et al., 2014; Rocher and Verdeil, 2013).

Alongside the expansion in natural gas use emerged infrastructure and institutional bodies to support its continued growth. After the discovery of natural gas fields in Tunisia, extension of the gas network became part of an energy security strategy to reduce oil-based energy imports (Bennasr and Verdeil, 2014; Rocher and Verdeil, 2013). Given the close marriage of electricity and natural gas sectors as explained above, STEG, already the monopolistic electricity distributor, became the monopoly gas distributor (ESMAP, 1999), thus encouraging its predisposition towards natural-gas based technology and infrastructure. The horizontal integration of gas distribution with electricity services also allowed STEG to maintain low-cost and reliable electricity supply by cross-subsidizing electricity deficits through surpluses in its natural gas activities (Cecelski et al., 2005; ESMAP, 1999). Finally, with the construction of the Trans-Mediterranean pipeline that transports natural gas from Algeria to Italy via Tunisia, Algerian

natural gas – paid out as a transit fee to Tunisia – became available to close any gaps between domestic supply and demand (Rekik et al., 2014).

Low electricity prices resulting from both upstream natural gas and direct electricity subsidies led to a surge in energy demand, transitioning Tunisia from a net exporter of oil and gas to a net importer. It increasingly relies on imported natural gas: in 2012, about 40% of its natural gas for electricity generation was imported from Algeria (Bridle et al., 2014). Due to the coupling of the domestic gas and electricity industries under STEG, the electricity sector is particularly vulnerable to changes in the gas market. In particular, the fall in domestic production of gas, combined with domestic electricity and gas prices set below cost recovery, have constrained STEG's financial capacity and ability to invest in electricity infrastructure. The Ministry of Finance has to cover STEG's revenue gap through a direct subsidy. However, as electricity demands grow, so too does Tunisia's fiscal deficit: in the past ten years, spending on energy subsidies has quadrupled and now represents one fifth of public spending, exceeding the amount spent on other social programs for health and employment (The World Bank Group, 2015).

This crowding out of investment in human capital has added to Tunisia's issues with unemployment and economic stagnation – key grievances that led to political unrest in the past (Arief, 2012). Historically, state-owned enterprises such as STEG were used as tools for job creation as the state would mandate employment and salary levels (The World Bank Group, 2014a). In 2010, for example, STEG was the largest employer in Tunisia (The World Bank Group, 2014a). However, this state-led model for economic development is no longer sustainable due to accumulating inefficiencies and fiscal deficits (The World Bank Group, 2014b).

Given these budgetary imbalances, the national government, under pressure from the IMF, has attempted to reform energy subsidies several times. However, these reforms were often quickly reversed in response to public protests and political unrest (Blatter and Buzzell, 2013). The delicate post-revolution environment has magnified government fears of instability, leaving politicians apprehensive to embark on reform. However, underpinning this social contract of subsidies are structural deficiencies within the

energy system: a natural-gas dependent electricity system, underinvestment in energy infrastructure, excessive energy consumption, as well as a population with expectations of cheap electricity.

4.2.2 The seeds of disruption

Despite mounting fiscal and international pressure for FFSR, policymakers in Tunisia are reluctant to reduce subsidies. Past attempts at subsidy reform, coerced through conditional loans from the IMF, spurred unrest and instability, leaving a legacy of fear of disrupting the social contract built on subsidies. These past reform attempts often generated opposition as they were implemented against a backdrop of growing social discontent, rising unemployment and living costs, and the perception that the government prioritized international requests over domestic matters (Blatter and Buzzell, 2013). As an alternative to past FFSR attempts in Tunisia, renewable energy policy may offer an attractive intervention point for subsidy reform for three reasons. Firstly, the political economy of the *energy system* underlying fossil fuel subsidies is less complicated than the social contract in which subsidies are embedded. Tunisia has long been a regional leader in supporting renewable energy and energy efficiency. Since the 1980's, Tunisia has had a proactive renewable energy policy (Laumanns et al., 2012). Already in 1985, it set up a specific agency for renewable energy and energy efficiency development. More recently in 2012, it established the Tunisian Solar Plan (TSP) that provides a regulatory and strategic framework for renewable energy deployment. This plan defines renewable energy targets of 15% for wind and 10% for solar PV in terms of installed capacity by 2030 and has helped increase investor confidence in Tunisia's commitment to renewable energy support (Waissbein et al., 2014).

Secondly, renewable energy IPPs are poised to enter the Tunisian power market at a time of growing dissatisfaction with STEG. As a relatively unchallenged vertically integrated utility, STEG has been criticized for its resistance to technological innovation, instead choosing to rely on proven thermal technologies and inefficient equipment suppliers. When STEG did attempt to diversify into renewables, the wind energy project met local opposition largely as a result of STEG's mismanagement and centralized approach to project development (Rocher and Verdeil, 2013). This growing perception of STEG's limitations as well as a precedent of two successful natural gas IPPs and the emergence of clean

energy equity investors has propelled the idea that private power producers can provide the diversification that Tunisia needs to increase energy security (Waissbein et al., 2014). In turn, IPPs have gained greater power in steering regulation towards greater transparency in order to lower the playing field for renewable energy technologies (Rocher and Verdeil, 2013).

Finally, given Tunisia's relatively mature industrial base and skilled workforce, local integration of wind and solar PV industries are realistic (Lynch and Hackwell, 2012). Unemployment, particularly youth unemployment, remains an issue in Tunisia as economic activity has stagnated in low-productivity sectors (The World Bank Group, 2014b). Building up a local renewable energy industry is predicted to create direct and indirect jobs at a lower cost than creating jobs in the gas sector (Rekik et al., 2014), thus potentially mitigating some of the social grievances that presently pose barriers for subsidy reform.

Figure 3: Projected marginal costs of electricity generation in Tunisia.

Unlike in South Africa, deployment of utility-scale wind and solar PV in Tunisia is limited. However, modelled electricity costs of wind and solar PV, shown in Figure 3, reach cost-competitiveness with unsubsidized new-build and operating natural gas power plants. Wind, in particular, is already cheaper

than new-build unsubsidized natural gas-fired generation. Towards the end of the modelling timeframe, wind and solar PV are even competitive with the unsubsidized operating costs of existing power plants.

These quantitative results demonstrate the potential for wind and solar PV to undermine the technical basis for natural gas subsidies by preventing the construction of new and eventually displacing existing natural gas power plants. This renewable energy deployment would not only reduce Tunisia's dependence on natural gas, but it would also result in fiscal savings for each MW of deployment. Theoretically, the fiscal savings resulting from renewable energy deployment also translate into increased capacity for the government to implement social safety nets to ease the transition to unsubsidized energy prices in the short term, and invest in human capital in the long-term.

5 Renewable energy policy as an enabler for fossil fuel subsidy reform?

In this paper, we took a socio-technical perspective of fossil fuel subsidies and analyzed how the technological system (and its evolution) contributes to the creation of fossil-fuel subsidy lock-in and how incentivizing technological change can help to overcome this lock-in. Figure 4 summarizes how our findings integrate into and expand the existing perspectives on subsidy reform. .

Figure 4: The lock-in of fossil fuel subsidies from a socio-technical perspective

Economic and political economy literature has largely focused on the feedbacks between *politics* (see Number 1 in Figure 3) and the *economy* (2) that stem from fossil fuel subsidy provision, framing subsidies as a form of political rent (3) to promote economic stability, growth and equity (4). In South Africa, for example, low-cost electricity – and even sometimes capital investments – provided by the public utility directly fueled the mining sector – a key industrial sector. In Tunisia, fossil fuel subsidies were introduced as a form of social protection, as they allowed the utility to rapidly expand electricity services. While these developmental objectives have often been a key motivation for initial fossil fuel subsidy provision, once introduced, fossil fuel subsidies often become embedded in the social contract (5) between political leaders and society, as evidenced by pressure to limit energy price increases in both South Africa and Tunisia. Growing fiscal deficits (6) and recognition of the inefficiency of fossil fuel subsidies (7) motivated a fiscal tightening approach to reform. In Tunisia, subsidy reforms were implemented as a

conditionality on IMF lending. Yet these economic or political economic approaches overlook the role of the *technological system* (8) in reinforcing fossil fuel subsidies.

As identified in literature taking an energy planning perspective, fossil fuel subsidies encourage investment in fossil fuel-based generation assets (9) with high fixed costs and long operating lifetimes. However, technological systems also encompass complementary networks and infrastructure (10). In some cases, these complementary capital investments are themselves a subsidy to the fossil fuel industry, as the case of public railways for coal transport in South Africa or the natural gas network in Tunisia. These complementary investments unlocked the possibility to cross-subsidize between export and domestic fossil fuel markets and increased the attractiveness of continued investments in fossil fuels by creating positive network externalities. Due to learning effects (11) also, a utility's increasing competency in fossil fueled technologies can result in a technological lock-in – an outcome particularly pronounced in both countries reviewed in this paper, with each having an electricity system almost wholly reliant on one fuel type. These positive feedbacks result in an undiversified energy system dependent on fossil fuels and thus highly sensitive to fuel price changes.

However, our analysis shows that the technological system underlying fossil fuel subsidies is also *systemically* linked to the economic and political dimensions of subsidies. The provision of artificially cheap electricity encourages an energy-intensive national economy. Sudden removal of subsidies could then have harmful effects not solely on household incomes directly, but also on *local industry* and *jobs* (12); many policymakers are unwilling to risk such widespread economic destabilization. This is the case in both South Africa, where employment and capital accumulation are high in energy-intensive sectors, and Tunisia, where the largest employer was the natural gas and electricity utility itself. Furthermore, in South Africa especially, there is a symbiotic relationship between the fossil fuel producing industry and the electric utility. The low-cost electricity historically provided by Eskom was only possible due to the cheap coal provided by coal mining companies.

While subsidies themselves are regarded as a political tool, fossil fuel-based technologies can also exhibit inherently political characteristics. Large centralized fossil fuel generation and production are conducive to centralized governance and consolidation of *market power* (13) (Winner, 1980). . Fossil fuel subsidies exacerbate this market power by providing rents to fossil-fuel incumbents, which leads to the formation of a network of powerful coalitions with *vested interests* (13) in maintaining their dominance (Moe, 2010). Eskom's interests in South Africa's electricity planning is clear even in the latest IRP, which projects a need for substantial centralized generation capacity from coal and nuclear power stations. This self-reinforcing system entrenches fossil fuel subsidies in not only economic and political, but also technological structures.

Attempting to remove fossil fuel subsidies directly has been difficult. In countries with indirect subsidies, which are more often found in large fossil fuel producing countries such as South Africa, subsidy removal is often never even raised as an issue. In countries where direct fossil fuel subsidy provision has often been used as a transparent way of bestowing benefits to certain interest groups (Victor, 2009), as in Tunisia, taking them away has been equally transparent and met with popular opposition. Renewable energy policies, on the other hand, have proven popular, even in countries that subsidize fossil fuels: at the end of 2015, 146 countries had enacted renewable energy policies (REN21, 2016) compared to only 40 countries with carbon pricing instruments (World Bank, 2016) – a policy that also transparently penalizes energy-intensive groups and fossil fuel incumbents. While grid-connected renewables do have technological characteristics and intricacies that make them distinct from conventional technologies, on the most basic level, renewable energy technologies simply provide electricity to meet end users' demands and thus can generally serve as substitutes for fossil fuel-based technologies. At the same time, these technological intricacies are also the critical 'seeds of disruption' (Arthur, 2009) that can instigate dynamics to overcome the lock-in of fossil fuel subsidies.

Renewable energy policy supports more than just the diffusion of the themselves; it can also involve also an endogenous re-architecting of the organizational structure of an economy – the conceptualization of new business models; formation of local supply chains (Schmidt and Huenteler, 2016), markets (Nyggaard

and Hansen, 2015) and jobs (Cantore et al., 2016); development of new codes and standards etc. – as societies adapt with these technologies (Arthur, 1989). In this way, renewable energy policies may also alter the power structure and interests of actors and decrease the legitimacy of fossil fuel subsidies (Isley et al., 2015; Matsuo and Schmidt, 2017; Meadowcroft, 2011; Meckling et al., 2015) in national FFSR debates. Furthermore, an important particularity of renewable energy technologies is that they can typically be installed more quickly than conventional technologies. Positive policy feedbacks can therefore be created in a – for energy sector standards – fast way (e.g., one can compare the rapid development of renewable energy projects by IPPs in South Africa to the often delayed coal power plant commissioned by Eskom). As such, policies that support the rise of new, alternative technologies can provide new intervention points for subsidy reform. The effects of strong renewable energy policy could be observed in Germany, where the policy-backed rise of a renewable energy industry helped undermine arguments in favor of extending existing coal production subsidies (Meyer et al., 2010). Also in Indonesia, after failed attempts to simply phase out kerosene subsidies for cooking, technology-oriented policies, which incentivized a significant amount of consumers to switch to alternative cookers running on cleaner liquefied petroleum gas, enabled the reduction of kerosene subsidies (Beaton and Lonton, 2010). Finally, in South Africa, although the nature of its coal subsidies does not allow for explicit subsidy removal, evidence suggests that both direct and indirect subsidies are waning. Eskom's current coal contracts are expiring and future domestic prices for coal are unlikely to reach to the historically low levels of the past, with public enterprises either unable or unwilling to make the necessary investments to enable these contracts. While part of this pivot away from coal can be attributed to external forces, such as decreasing international coal prices, arguably the rise of cheap renewables played a role in eclipsing the necessity of public support for domestic coal fired power generation. In Tunisia, in contrast, renewable energy policies and the industry are not as well developed, yet. South Africa's electricity crisis of 2008 seems to have opened a 'window of opportunity', which Tunisia has not seen. Also, due to the higher investment risks (Wassbein et al, 2013, 2014), which affect wind and PV much more than gas-fired power stations

(Schmidt, 2014), and lower technological capabilities, more international support might be needed in order to kick off positive dynamics (see below).

Planting ‘seeds,’ however, is not straightforward, faces opposition, and thus requires a degree of strategy in policy design. For example, by framing the REIPPPP as an industrial policy, South African policymakers could gain both initial political buy-in to the policy as well as potentially grow a ‘green’ coalition that would reinforce support for low-carbon policy. While in theory such a strategy may be effective, national policies must also consider how policy design choices succeed (or fail) in building such coalitions in practice. For example, the shares and location of the renewable energy technology value chain – and thus the actors strengthened by the renewable energy policy – will differ across technologies and are highly dependent on country capabilities (Schmidt and Huenteler, 2016). As local content requirements entail a tradeoff between greater investment risk and greater industrial benefits, rather than mandating local content requirements across a suite of technologies, policymakers could design more targeted policies that specify the technologies and components most likely to generate local value – both economically and politically.

Our analysis also has implications for international support for FFSR. Past international interventions, such as conditional loans by the IMF, often merely focused on creating incentives to phase out fossil-fuel subsidies and did not account for the underlying technological foundations of fossil fuel subsidies. As a result, these interventions often only had short-term effects, with many countries experiencing policy back-sliding (Lockwood, 2015). From a socio-technological perspective on fossil fuel subsidies, however, technologies and policies that destabilize the subsidy regime offer an alternative outlet for future international support for FFSR. For example, financial assistance can be leveraged both to directly support renewable energy deployment and to indirectly foster the build-up of local renewable energy technology supply chains and jobs. Technical assistance can help remove non-financial barriers to renewable energy technologies, such as grid integration support, regulatory reforms, or policy de-risking (Schmidt, 2014; Waissbein et al., 2013). Unlike traditional fiscal reform measures, these support mechanisms that embed FFSR within a broader renewable energy policy package may garner greater public acceptance and avoid

the scapegoating of the international organization. These support policies can theoretically be combined with the commonly used incentives to phase out fossil fuel subsidies (Matsuo and Schmidt, 2017).

To conclude, the political supply of and demand for fossil fuel subsidies is not the sole source of subsidy persistence; rather, this social contract is also a symptom of the larger socio-technical system with which subsidies evolved. Past FFSR strategies that combined fiscal reform with compensation payments to affected interest groups did therefore not reach far enough, resulting in the oft-observed backsliding. Providing support for low-carbon technologies, conversely, likely entails a natural sunset clause: low-carbon technological change leads not only to convergence of renewable energy costs with fossil-fueled generation costs (e.g., due to cost reductions from technological learning), but also tackles the electricity baseline that perpetuates the demand for fossil fuel subsidies. As such, it can help address both direct and indirect fossil fuel subsidies. Once the renewable energy sector has reached a critical mass, the political feasibility of subsidy reform increases. Combining these approaches might therefore increase the stickiness of FFSR. This paper represents only an initial exploration to a socio-technical perspective of FFSR. In order to further test this hypothesis, future research could investigate the specific combinations of mechanisms, technology-, and country-contexts that can lead to the destabilization of the fossil fuel subsidy regime.

6 References

- African Mining Intelligence, 2016. Exxaro seeks IPPs to develop Waterberg coal mine. Indigo Publ.
- Altieri, K.E., Trollip, H., Caetano, T., Hughes, A., Merven, B., Winkler, H., 2016. Achieving development and mitigation objectives through a decarbonization development pathway in South Africa
Achieving development and mitigation objectives South Africa. *Clim. Policy* 16, S78–S91.
doi:10.1080/14693062.2016.1150250
- Arief, A., 2012. Political transition in Tunisia. *Curr. Polit. Econ. Africa* 5, 287–327.
- Arthur, W.B., 2009. *The Nature of Technology: What it is and how it evolves*. Penguin Group, London.
- Arthur, W.B., 1989. Competing technologies, increasing returns, and lock-in by historical events. *Econ. J.* 99, 116–131.
- Arze del Granado, F.J., Coady, D., Gillingham, R., 2012. The Unequal Benefits of Fuel Subsidies: A Review of Evidence for Developing Countries. *World Dev.* 40, 2234–2248.
doi:10.1016/j.worlddev.2012.05.005
- Baker, L., 2016. *Technology Development in South Africa: The Case of Wind and Solar PV*, SPRU Working Paper Series (SWPS). SPRU Working Paper Series (SWPS), Sussex.
- Baker, L., 2015. The evolving role of finance in South Africa's renewable energy sector. *Geoforum* 64, 146–156. doi:10.1016/j.geoforum.2015.06.017
- Baker, L., Newell, P., Phillips, J., 2014. The Political Economy of Energy Transitions: The Case of South Africa. *New Polit. Econ.* 19, 791–818. doi:10.1080/13563467.2013.849674
- Baker, L., Sovacool, B.K., 2017. The political economy of technological capabilities and global production networks in South Africa's wind and solar photovoltaic (PV) industries. *Polit. Geogr.* 60, 1–12. doi:10.1016/j.polgeo.2017.03.003
- Bazilian, M., Onyeji, I., 2012. Fossil fuel subsidy removal and inadequate public power supply: Implications for businesses. *Energy Policy* 45, 1–5. doi:10.1016/j.enpol.2012.02.057
- Beaton, C., Lonton, L., 2010. Lessons Learned from Indonesia's Attempts to Reform Fossil-Fuel

Subsidies.

Belet Cessac, C., 2014. Analysis of the regulatory framework governing network access for producers of electricity from renewable energy sources in Tunisia. GIZ, Tunis.

Bennasr, A., Verdeil, E., 2014. An “Arab Spring” for Corporatization? Tunisia’s National Electricity Company (STEG)., in: McDonald, D.A. (Ed.), *Rethinking Corporatization: Public Utilities in the Global South*. Zed Books Ltd, London/New York, pp. 88–106.

Berkhout, F., 2002. Technological regimes, path dependency and the environment. *Glob. Environ. Chang.* 12, 1–4. doi:10.1016/S0959-3780(01)00025-5

Blatter, D., Buzzell, Z., 2013. The Subsidy Trap: Why Tunisia’s Leaders Are Unwilling, Unable, or Afraid to Abandon Fuel Subsidies. George Washington University.

Bridle, R., Kiston, L., Wooders, P., 2014. Fossil-Fuel Subsidies: A barrier to renewable energy in five Middle East and North African countries. IISD, Geneva.

Bridle, R., Kitson, L., 2014. The impact of fossil-fuel subsidies on renewable electricity generation. IISD, Geneva.

Burniaux, J.-M., Chateau, J., 2014. Greenhouse gases mitigation potential and economic efficiency of phasing-out fossil fuel subsidies. *Int. Econ.* 140, 71–88. doi:10.1016/j.inteco.2014.05.002

Burton, J., Winkler, H., 2014. South Africa’s planned coal infrastructure expansion: drivers, dynamics and impacts on greenhouse gas emissions. Energy Research Centre Research Report Series, Cape Town.

Cantore, N., Nussbaumer, P., Wei, M., Kammen, D., 2016. Promoting Renewable Energy and Energy Efficiency in Africa: A Framework to Evaluate Employment Generation and Cost-effectiveness.

CDM PDD, 2012a. Project 7796: Tunisia Sidi Daoud Wind Farm Project.

CDM PDD, 2012b. Project 8954: Coega IDZ Windfarm.

Cecelski, E., Ounalli, A., Aissa, M., Dunkerley, J., 2005. Rural Electrification in Tunisia: National Commitment, Efficient Implementation and Sound Finances. ESMAP, Washington, D.C.

Crickmay, 2009. Coaltech Transport Investigation. COALTECH.

- de Moor, A., 2001. Towards a grand deal on subsidies and climate change. *Nat. Resour. Forum* 25, 167–176.
- Durbach, I., Merven, B., McCall, B., 2017. Expert elicitation of autocorrelated time series with application to e3 (energy-environment-economic) forecasting models. *Environ. Model. Softw.* 88, 93–105.
doi:10.1016/j.envsoft.2016.11.007
- Eberhard, A., 2011. The future of South African coal: Market, investment, and policy challenges (No. 100), Program on Energy and Sustainable Development. Program on Energy and Sustainable Development, Stanford. doi:10.1017/CBO9781316136058.005
- Eberhard, A., 2007. The Political Economy of Power Sector Reform in South Africa, in: Victor, D.G., Heller, T.C. (Eds.), *The Political Economy of Power Sector Reform: The Experiences of Five Major Developing Countries*. Cambridge University Press, New York, pp. 215–253.
- Eberhard, A., Leigland, J., Kolker, J., 2014. South Africa’s Renewable Energy IPP Procurement Program: Success Factors and Lessons. The World Bank Group, Washington, D.C.
- Ellis, J., 2010. *The Effects of Fossil-Fuel Subsidy Reform : A review of modelling and empirical studies*. IISD, Geneva.
- Energy Monitor Worldwide, 2016. The Future of Eskom and South Africa’s coal sector will be nothing like its past. Syndigate Media Inc.
- ESMAP, 1999. *Increasing the Efficiency of Gas Distribution*. Washington, D.C.
- Eurostat, 2015. EU trade since 1988 by CN8.
- Fine, B., Rustomjee, Z., 1996. *The Political Economy of South Africa: From Minerals Energy Complex to Industrialisation*. Westview Press, Boulder.
- Fouquet, R., 2016. Path dependence in energy systems and economic development. *Nat. Energy* 1, 1–5.
doi:10.1038/nenergy.2016.98
- Geels, F.W., 2004. From sectoral systems of innovation to socio-technical systems - Insights about dynamics and change from sociology and institutional theory. *Res. Policy* 2004, 897.

- Geels, F.W., 2002. Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case-study. *Res. Policy* 31, 1257–1274. doi:10.1016/S0048-7333(02)00062-8
- Hochstetler, K., 2015. Green Industrial Policy and the Renewable Energy Transition: Can it be Good Industrial Policy?, in: *Red de Economia Politica de America Latina*. Montevideo. doi:10.1017/CBO9781107415324.004
- Huenteler, J., Niebuhr, C., Schmidt, T.S., 2016. The effect of local and global learning on the cost of renewable energy in developing countries. *J. Clean. Prod.* 128. doi:10.1016/j.jclepro.2014.06.056
- IEA, 2016. *World Energy Outlook*. Paris. doi:10.1787/weo-2016-en
- IEA, 2015. *World Energy Outlook*. Paris. doi:10.1787/weo-2014-en
- IEA, 2014a. *Africa Energy Outlook. A focus on energy prospects in Sub-Saharan Africa*. Paris.
- IEA, 2014b. *The Impact of Global Coal Supply on Worldwide Electricity Prices*. Paris.
- IEA, 2014c. *Technology Roadmap: Solar photovoltaic energy*. Paris. doi:10.1007/SpringerReference_7300
- IEA, 2013. *Technology Roadmap: Wind energy*. Paris. doi:10.1007/SpringerReference_7300
- IEA, 2011. *World Energy Outlook*. Paris.
- IPCC, 2006. *Guidelines for National Greenhouse Gas Inventories*. IGES, Japan.
- Isley, S.C., Lempert, R.J., Popper, S.W., Vardavas, R., 2015. The effect of near-term policy choices on long-term greenhouse gas transformation pathways. *Glob. Environ. Chang.* 34, 147–158. doi:10.1016/j.gloenvcha.2015.06.008
- Jenkins, J.D., 2014. Political economy constraints on carbon pricing policies : What are the implications for economic efficiency, environmental efficacy, and climate policy design? *Energy Policy* 69, 467–477. doi:10.1016/j.enpol.2014.02.003
- Jordan, A., Matt, E., 2014. Designing policies that intentionally stick: Policy feedback in a changing climate. *Policy Sci.* 47, 227–247. doi:10.1007/s11077-014-9201-x
- Kojima, M., 2016. *Fossil Fuel Subsidy and Pricing Policies: Recent Developing Country Experience*.

- Koplow, D., 2009. Measuring energy subsidies using the price-gap approach: What does it leave out?, IISD Trade, Investment and Climate Change Series. IISD, Winnipeg.
- Laumanns, U., Lehr, U., Mönning, A., Missaoui, R., Marrouki, S., 2012. Renewable energy and energy efficiency in Tunisia - employment, qualification and economic effects. GIZ, Tunis.
- Lockwood, M., 2015. Fossil Fuel Subsidy Reform, Rent Management and Political Fragmentation in Developing Countries. *New Polit. Econ.* 20, 475–494. doi:10.1080/13563467.2014.923826
- Lynch, D.K., Hackwell, J. a., 2012. Study on the renewable energy potential for electricity generation for national consumption in Tunisia and export to the EU. GIZ, Bonn.
- Matsuo, T., Schmidt, T., 2017. Hybridizing low-carbon technology deployment policy and fossil fuel subsidy reform: a climate finance perspective. *Environ. Res. Lett.*
- Mcrae, S., 2013. Infrastructure Quality and the Subsidy Trap. *Am. Econ. Rev.* 105, 35–66. doi:10.1257/aer.20110572
- Meadowcroft, J., 2011. Engaging with the politics of sustainability transitions. *Environ. Innov. Soc. Transitions* 1, 70–75. doi:10.1016/j.eist.2011.02.003
- Meckling, J., Kelsey, N., Biber, E., Zysman, J., 2015. Winning coalitions for climate policy. *Science* (80-.). 349, 10–11.
- Merrill, L., Bassi, A.M., Bridle, R., Christensen, L.T., 2015. Tackling Fossil Fuel Subsidies and Climate Change: Levelling the energy playing field. Nordic Council of Ministers, Copenhagen.
- Meyer, B., Küchler, S., Hölzinger, O., 2010. Staatliche Förderungen der Stein- und Braunkohle im Zeitraum 1950 - 2008. Berlin.
- Moe, E., 2010. Energy, industry and politics: Energy, vested interests, and long-term economic growth and development. *Energy* 35, 1730–1740. doi:10.1016/j.energy.2009.12.026
- Nygaard, I., Hansen, U.E., 2015. The conceptual and practical challenges to technology categorisation in the preparation of technology needs assessments. *Clim. Change* 131, 371–385. doi:10.1007/s10584-015-1367-5

- OECD, 2017. Exchange rates (indicator) [WWW Document]. doi:10.1787/037ed317-en
- OECD, 2016. Development aid rises again in 2015, spending on refugees doubles [WWW Document].
URL <http://www.oecd.org/dac/development-aid-rises-again-in-2015-spending-on-refugees-doubles.htm> (accessed 12.9.16).
- Parliamentary Monitoring Group, 2015. Republic of South Africa Department of Public Enterprises, Questions to the Minister No. 1623.
- Pierson, P., 2000. Increasing returns, path dependence, and the study of politics. *Am. Polit. Sci. Rev.* 94, 251–267.
- Rafey, W., Sovacool, B.K., 2011. Competing discourses of energy development: The implications of the Medupi coal-fired power plant in South Africa. *Glob. Environ. Chang.* 21, 1141–1151.
doi:10.1016/j.gloenvcha.2011.05.005
- Rekik, K., Ben Abdallah, M., Boussen, M., Chelbi, A., 2014. Une Vision Strategique pour le secteur de l’Energie - Reflections sur des themes prioritaires. The World Bank Group, Washington, D.C.
- REN21, 2016. Renewables 2016. Global Status Report. Paris.
- Rentschler, J., Bazilian, M., 2016. Reforming fossil fuel subsidies: drivers, barriers and the state of progress. *Clim. Policy* 3062, 1–24. doi:10.1080/14693062.2016.1169393
- Republic of South Africa Department of Energy, 2015. Renewable Energy IPP Procurement Programme Bid Window 4 Preferred Bidders’ Announcement.
- Republic of South Africa Department of Energy, 2013. Integrated Resource Plan for Electricity (IRP) 2010 - 2030: Update Report. Pretoria.
- Rip, A., Kemp, R., 1998. Technological change, in: Rayner, S., Malone, L. (Eds.), *Human Choice and Climate Change*. Batelle Press, Washington, D.C., pp. 327–399. doi:10.1007/BF02887432
- Rocher, L., Verdeil, E., 2013. Energy transition and revolution in Tunisia: Politics and spatiality. *Arab World Geogr.* 16, 267–288.
- Schmidt, T.S., 2014. Low-carbon investment risks and de-risking. *Nat. Clim. Chang.* 4, 237–239.

- Schmidt, T.S., Born, R., Schneider, M., 2012. Assessing the costs of photovoltaic and wind power in six developing countries. *Nat. Clim. Chang.* 2, 548–553. doi:10.1038/nclimate1490
- Schmidt, T.S., Huenteler, J., 2016. Anticipating industry localization effects of clean technology deployment policies in developing countries. *Glob. Environ. Chang.* 38, 8–20.
- Schwanitz, V.J., Piontek, F., Bertram, C., Luderer, G., 2014. Long-term climate policy implications of phasing out fossil fuel subsidies. *Energy Policy* 67, 882–894. doi:10.1016/j.enpol.2013.12.015
- Societe Tunisienne de l'Electricite et du Gaz, 2014. Les tarifs du gaz.
- Stats SA, 2017. Quarterly Labour Force Survey.
- The World Bank Group, 2016. Commodity price data monthly prices.
- The World Bank Group, 2015. The Socioeconomic Impacts of Energy Reform in Tunisia A Simulation Approach. Washington, D.C.
- The World Bank Group, 2014a. Pour une Meilleure Gouvernance des Entreprises Publiques en Tunisie. Washington, D.C.
- The World Bank Group, 2014b. The Unfinished Revolution: Bringing opportunity, good jobs and greater wealth to all Tunisians, Development Policy Review. Washington, D.C. doi:10.1353/jod.1991.0032
- Tushman, M.L., Rosenkopf, L., 1992. Organizational Determinants of technological change: Toward a Sociology of Technological Evolution. *Res. Organ. Behav.* 14, 311–347.
- UNFCCC, 2009. Draft decision - / CP.15. Conf. Parties to Clim. Chang. Conv.
- UNFCCC, 2007. Methodological tool to calculate the emission factor for an electricity system (Annex 12, EB 35).
- Unruh, G.C., 2000. Understanding carbon lock-in. *Energy Policy* 28, 817–830. doi:10.1016/S0301-4215(00)00070-7
- Verbong, G., Geels, F., 2007. The ongoing energy transition: Lessons from a socio-technical, multi-level analysis of the Dutch electricity system (1960-2004). *Energy Policy* 35, 1025–1037.
- Victor, D., 2009. The Politics of Fossil-Fuel Subsidies. IISD, Geneva.

Waissbein, O., Deenapanray, S., Kelly, R., 2014. Tunisia: Derisking Renewable Energy Investment.

UNDP, New York and Tunis.

Waissbein, O., Glemarec, Y., Bayraktar, H., Schmidt, T., 2013. Derisking Renewable Energy Investment.

UNDP, New York.

Walwyn, D.R., Brent, A.C., 2014. Renewable energy gathers steam in South Africa. *Renew. Sustain.*

Energy Rev. 41, 390–401. doi:10.1016/j.rser.2014.08.049

Winner, L., 1980. Do Artifacts Have Politics? *Daedalus* 109, 121–136.

World Bank, 2016. State and Trends of Carbon Pricing, Washington, DC: World Bank. Washington, D.C.

doi:10.1596/978-1-4648-0268-3

Appendices

Appendix A: Model overview

Marginal baseline generation costs are calculated using both subsidized and unsubsidized fuel inputs.

When renewables are deployed, they may impact the marginal baseline in two ways (UNFCCC, 2007): by displacing existing baseline plants – known as the operation margin (OM) — or by delaying/preventing the construction of new business-as-usual plants – known as the build margin (BM). In calculating the OM for each technology j in each year t , only operating costs, including fuel costs (F) and operations and maintenance ($O\&M$) costs, are considered:

$$OM\ Cost_{j,t} = \frac{O\&M_{j,t} + \frac{F_{j,t} \times E_{j,t}(1-T)}{\eta}}{E_{j,t}(1-T)} \quad \text{Eq. (A.1)}$$

where T is the country's tax rate and E is the annual electricity generation for each technology type. The BM is calculated as the levelized cost of electricity (LCOE), or the cost of generating one unit of electricity accounting for all costs as well as expected electricity generation of the technology over its lifetime:

$$BM\ Cost_{j,t} = \frac{SE_{j,t} \times INV_{j,t} + \sum_{\tau=1}^N \frac{O\&M_{j,t} + \frac{F_{j,t} \times E_{j,t}(1-T)}{\eta} + Debt_{j,\tau} - T \left(I_{j,\tau} + D_{j,\tau} + O\&M_{j,t} + \frac{F_{j,t} \times E_{j,t}(1-T)}{\eta} \right)}{(1+K_E)^\tau}}{(1-T) \sum_{\tau=1}^N \frac{E_{j,\tau}}{(1+K_E)^\tau}} \quad \text{Eq. (A.2)}$$

where SE is the share of the investment covered by equity investors, INV is the investment cost, η is the efficiency of the power plant, $Debt$ are the principal and interest payments on debt, I is the interest expense, D is depreciation and K_E is the cost of equity and τ is the operating year of the plant.

Wind and solar PV generation costs were also calculated as LCOEs. For these technologies, investment costs decrease endogenously with cumulative installed capacity due to technological learning at both the global and local levels (Huenteler et al., 2016):

$$INV_{j,t} = (1+i)^t \cdot INV_o \left(\alpha_{j,local} * \frac{Y_{j,t,local}}{Y_{j,o,local}}^{\log_2(1-LR_{j,local})} + \alpha_{i,global} * \frac{Y_{j,t,global}}{Y_{j,o,global}}^{\log_2(1-LR_{j,global})} \right) \quad \text{Eq. (A.3)}$$

where α_{local} and α_{global} are the shares of local and global learning, respectively; Y_{local} is the cumulative installed capacity within the case country, determined by each case country's deployment trajectory; Y_{global} is IEA's projected global cumulative installed capacities (IEA, 2014c, 2013); i is the inflation rate, and LR_{local} and LR_{global} are the assumed local and global learning rates for each technology. O&M expenses for the RETs were assumed a constant percentage of investment cost and therefore are also subject to learning over time. Although the baseline technologies are mature, it is reasonable to expect some cost decreases due to learning. For these technologies, it was assumed the effect of learning would balance the effect of inflation. The modelling case assumes a 10 year phase-in of wind or solar PV to meet a 10% renewable energy generation target. The 10% target is sufficiently high to foster a local business context required for enabling interactive learning between relevant actors but low enough to prevent major grid stability issues (Schmidt et al., 2012).

Appendix B: Model assumptions and data

Table B.1: Technology inputs

	Natural gas	Coal	Wind	Solar PV
<i>Initial investment (USD₂₀₁₆/MW_e)¹</i>	910,000	1,755,000	1,700,000 ³	1,630,000 ³
<i>Annual O&M expense (USD₂₀₁₆/MW_e)¹</i>	35,100	50,000	17,987 ³	15,000 ³
<i>Plant lifetime, years¹</i>	25	40	20	20
<i>Emissions factors, (tCO₂/MWh_{th})⁴</i>	0.195	0.34	-	-
<i>Plant efficiency¹</i>	52.7%	37%	-	-
<i>Loan tenor, years⁵</i>	12.5	20	10	10

¹(Waissbein et al., 2013)

³Tunisia, in starting year of modelling timeframe

⁴(IPCC, 2006)

⁵Loan tenors were assumed equal to half the project lifetime

Table B.2: Country resource inputs

	Natural gas	Coal	Wind	Solar PV
Operating margin				
<i>Tunisia¹</i>	100%	-	-	-
<i>South Africa²</i>	-	100%	-	-
Build margin				
<i>Tunisia¹</i>	100%	-	-	-
<i>South Africa²</i>	-	100%	-	-
Full load hours				
<i>Tunisia³</i>	7000	-	2,628	1,910
<i>South Africa²</i>	-	5548	3,424	2,003
Generation target (GWh)				
<i>Tunisia³</i>	-	-	2,381	2,381
<i>South Africa⁵</i>	-	-	33,291	33,291

¹(CDM PDD, 2012a)

²(CDM PDD, 2012b)

³(Waissbein et al., 2014)

⁴(Waissbein et al., 2013)

⁵(Republic of South Africa Department of Energy, 2013)

Table B.3: Country financing inputs

	Share of equity financing	Share of debt financing	K _E ³ , baseline tech.	K _D ³ , baseline tech.	K _E ⁴ , RE tech.	K _D ⁴ , RE tech.	Corporate Tax rate
<i>Tunisia¹</i>	25%	75%	10.80%	4.76%	12.7%	5.6%	25%
<i>South Africa²</i>	30%	70%	11.73%	5.95%	13.8%	7.0%	28%

¹(Waissbein et al., 2014)

²(Waissbein et al., 2013)

³Costs of capital and debt for the baseline technologies were discounted 15% to account for their relative maturity compared to wind and solar PV

⁴The de-risked costs of capital were utilized in the model

Table B.4: Learning parameters¹

	Wind	Solar PV
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<i>Share of local learning</i>	67%	43%
<i>Share of global learning</i>	33%	57%
<i>Local learning rate</i>	11.3%	17%
<i>Global learning rate</i>	4.3%	20%

¹(Huenteler et al., 2016)

Figure B.1: Subsidized and world fuel prices

In estimating subsidies, the price gap approach, or difference between the actual energy price and a reference price, was used. In this model, subsidies were built in through subsidized fuel inputs, which then reduce downstream wholesale costs of electricity, as this resembles the subsidization mechanism in both Tunisia and South Africa. The subsidized price was assumed constant in real terms over the modelling timeframe and reference prices followed the fuel price trajectories outlined in the IEA's World Energy Outlook "New Policies" scenario (IEA, 2015).

In Tunisia, the starting reference price of natural gas was taken as the average import price of Algerian natural gas into Italy (Eurostat, 2015). Given that Tunisia receives gas from Algeria via the same pipeline

that transports this gas to Italy, no adjustment for transport costs was made. The subsidized price was taken as STEG's transfer prices for natural gas IPPs (Societe Tunisienne de l'Electricite et du Gaz, 2014). In South Africa, the starting reference price of coal is the Richard's Bay Free on Board (FOB) price (The World Bank Group, 2016) corrected for energy content and adjusted for freight costs. Per tonne prices of export and domestic coal in South Africa are not directly comparable due to energy content differences. We assumed the energy content of domestic coal to be 20MJ/kg and export grade coal to be 25MJ/kg (Burton and Winkler, 2014). Freight costs were calculated assuming coal is transported via unsubsidized railway using data from a study on South African coal transport costs (Crickmay, 2009). The subsidized price was taken as the weighted average price for Eskom's existing coal contracts (Parliamentary Monitoring Group, 2015).