Chapter 4
Impacts of Electricity Subsidies Policy on Energy Transition

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Abstract Energy subsidy programmes are socio-economically designed to offer a modern and affordable energy, accessible for specific social groups, protect domestic industry, simulate economic development and protect the environment. However, in several countries, energy subsidies have deviated from their objectives and become an energy budget burden and a sustainable development barrier. Many questions arise: what are exactly energy subsidies? How are they implemented in a country mechanism? And what are their real effects?

This Chapter presents a review of energy subsidies: definitions, typologies, measurement approaches and effects. Facing harmful energy subsidies, reforms are also examined to help decision-makers phase out energy transition barriers related to subsidies. The case of the Tunisian power system is displayed in deeper details, characterised with a heavy burden of end-users electricity subsidies and an energy transition aiming 30% of renewable energies by 2030, against 3% in 2019. Using a holistic approach, based on hybrid energy systems modelling, has allowed presenting insights on reforming electricity subsidies and achieving sustainable development. This approach links subsidies, pricing, emissions, demand and supply of the power system through the advanced version of OSeMOSYS. Dynamics between energy, economics and environment are appealed within an integrated analysis of electricity subsidies policy.

Keywords Energy subsidies · Electricity pricing · Hybrid modelling · OSeMOSYS · Tunisian system · Econometric approach · Optimisation modelling · Reform policy

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1 Introduction

Local energy pricing policies is a governmental intervention in energy markets targeting social, economic and environmental objectives. Commonly known as energy subsidies (ES), this policy facilitates access to basic fuels, e.g. diesel, electricity and liquefied petroleum gas, etc. Subsidy programmes are originally designed to make modern energy affordable and accessible for specific social groups or in rural areas, protect domestic industry from competition, simulate economic and regional development and protect the environment (Fattouh and El-Katiri 2012). Taking into consideration these numerous benefits that Governments try to reach through energy subsidies, what are exactly energy subsidies? How are they implemented in a country mechanism? And what are their real effects? This chapter pleads energy subsidies by bringing answers to these questions. Section 2 reviews energy subsidies, followed by Sect. 3 analysing renewable energy (RE) subsidies. Then, Sect. 4 will overview the benefits, challenges and costs of ES reform, and present methodologies for the identification of *harmful energy subsidies* and designing their reform. Ultimately, in Sect. 5 the case study about the power system of Tunisia is analysed. Applicable electricity subsidies definition in Tunisia are identified, existing types and their effects are reviewed, and different Government interventions for electricity, electrification and RE subsidies are cited. In order to present holistic insights on the power system, this chapter relies on an advanced version of Open Source energy MOdelling SYStem "OSeMOSYS", i.e. a hybrid cost-based model relating electricity demand and supply through long-term optimisation.

Based on simulation results, recommendations to policy makers will be presented on how to reform electricity subsidies in Tunisia to achieve energy transition.

2 Review of Energy Subsidies

2.1 Definitions

Given the areas that subsidies are covering, there is no fit-all definition; and even within the energy sector the same problematic is faced. Many works have defined ES, where they agree about common points and differ about others. Given the developed literature of international organisations in terms of energy economics, their definitions of ES are taken into consideration in this work, listed in the Box 4.1.

The common point in these definitions is built around the principle that ES is a Government intervention. However, definitions differ about the target (consumer and/or producer), type of Government intervention (financial or in-kind) and effects on market prices.

Box 4.1: Energy Subsidies Definitions

United Nations (UN) Statistical Office definition based on the System of National Accounts (SNA)

Subsidies are current unrequited payments that Government units, including non-resident Government units, make to enterprises on the basis of the levels of their production activities or the quantities or values of the goods or services which they produce, sell or import (Von Moltke et al. 2004).

World Trade Organisation (WTO) Agreement on Subsidies and Countervailing Measures (ACMS)

A "subsidy" exists when there is a "financial contribution" by a Government or public body that confers a "benefit". A "financial contribution" arises where: (i) a Government practice involves a direct transfer of funds (e.g. grants, loans, and equity infusion), potential direct transfers of funds or liabilities (e.g. loan guarantees); (ii) a Government revenue due which is foregone or not collected (e.g. fiscal incentives such as tax credits); (iii) goods or services other than general infrastructure or purchased goods provided by the Government; or (iv) an entrusted or directed private body by the Government to carry out one or more of the above functions.

All WTO members accept this subsidy definition (Sovacool 2017).

Organisation for Economic Co-operation and Development (OECD) definition

ES are measures that keep prices for consumers below market levels or for producers above market levels, or reduces costs for consumers and producers (Kleinbard 2010). Within the European Union, there isn't any common designation of ES.

United Nations Environment Programme (UNEP) definition

During the twenty-first century, UNEP considers ES any Government action that influences energy market outcomes by lowering the cost of energy production, raising the price received by energy producers or lowering the price paid by energy consumers. Governments like to keep subsidies "off-budget" for political reasons, since "on-budget" subsidies are an easy target for pressure groups interested in reducing the overall tax burden (Steenblik 2003).

US Energy Information Administration (EIA) and International Energy Agency (IEA) definition

Both institutions have defined an energy subsidy as any Government action designed to influence energy market outcomes, whether through financial incentives, regulation, research and development or public enterprises, which lowers the cost of energy production, raises the price received by energy producers, or decreases the price paid by energy consumers (Brown 2001).

International Monetary Fund (IMF) definition

Energy subsidies comprise both consumer and producer subsidies. Consumer subsidies arise when the prices paid by consumers, including both firms (intermediate consumption) and households (final consumption), are below a benchmark price, while producer subsidies arise when prices received by suppliers are above this benchmark price (Fisher and Rothkopf 1989).

2.2 Typology

The classification of energy subsidies is highly related to their definitions. Some definitions include parameters and ignore others. These parameters are generally:

- Pathway benefits (direct or indirect, explicit or implicit, on-budget or off-budget)
- Target (consumer or producer, input or output)
- Instrument (budget, tax, transfer, assets)
- Purpose (regional development or energy conservation).

Previous research works where based on one of these parameters to classify subsidies mechanisms. However, the same mechanism could be classified under different categories. For example, a loan could be a financial transfer, direct and for a consumer. Table 4.1 summarises the different mechanisms.

2.3 Measurement

The task of measuring and comparing ES across countries or on a national basis might be highly complex and complicate their reform. This is due to the differences in definitions, classifications, the degree of transparency of fiscal systems and the complexity of energy systems. The attempt studies about quantifying energy subsidies are very limited given the lack of data and the complexity of the tasks (Von Moltke et al. 2004).

Sections 2.3.1, 2.3.2, 2.3.3 and 2.3.4 are the most common approaches for measuring ES which have been mentioned and applied by international organisations.

2.3.1 The Price Gap Approach

It is the most commonly applied method to calculate subsidies and is based on a comparison of the average end-use prices paid by consumers with reference prices presenting the full cost of the supply. In a given economy, the basic calculation of subsidies for a product is expressed in Eq. 4.1:

$$Subsidy = \left(Reference\ price - End\_user\ Price\right) \times Units\ consumed \tag{4.1}$$

Where:

- Reference price represents the supply cost — in electricity field: generation, transmission and distribution costs— plus the value added taxes (VAT);
- End_user price represents the price paid by the final consumer;
- Units consumed are the amount of energy consumed per unit; for e.g. quantity of kWh consumed.

Table 4.1 Classification of energy subsidies The Price Gap Approach

Government interventions	Definitions/schemes	Sources	Effects on prices	Classification parameters
Direct financial transfers	Grants to producers, low-interest or preferential loans to producers	Sovacool (2017)	Lower production's cost	Transfer, direct, consumers and producers
	Grants to consumers		Lower consumer's price	
Preferential tax treatments	Rebates or exemption on royalties, duties, producer levies and tariffs	Sovacool (2017)	Lower production's cost	Tax, consumers and producers
	Tax credit		Lower production's cost and consumer's price	
	Accelerated depreciation allowances on energy supply equipment		Lower production's cost	
Tax expenditures	Related to final consumption, typically targeted at households	Kleinbard (2010)	Lower consumer's price	Tax, consumers and producers
	Related to energy as inputs to production: Targeted at fuels or electricity, used as input to the final production of another good or service.		Lower production's cost	
	Related to energy production: Targeted at the actual extraction and production of energy, including refining and transport.		Lower production's cost and consumer's price	
Government revenue foregone	Governments also forego revenue by offering the use of non-depletable (e.g. land) or depletable assets (e.g. fossil-fuel resources) under their control to a private company (or individuals) to exploit them for their own use or for sale	Steenblik (2003)	Lower production's cost or consumer's price	Asset, consumers and producers, regional development

(continued)

Table 4.1 (continued)

Government interventions	Definitions/schemes	Sources	Effects on prices	Classification parameters
Regulation of the energy sector	Demand guarantees and mandated deployment rates	Sovacool (2017)	Lower production's cost and raise price to producer	Energy conservation
	Price controls		Raise the price to producers and lower it to consumers	
	Market-access restrictions and preferential planning consent and controls over access to resources		Raise price to producers	
Energy-related services provided by Government at less than full cost	Direct investment in energy infrastructure	Sovacool (2017)	Lower production's cost	Development, direct, explicit, budget
	Public research and development		Lower production's cost	
Trade restrictions	Quota, technical restrictions and trade embargoes	Sovacool (2017)	Raise price to producer	Producers, indirect
Failure to impose external costs	Environmental externality costs	Brown (2001)	Lower consumer's price	Off-budget
	Energy security risks and price volatility costs		Lower consumer's price	
Depletion allowance	Allow gross income deduction up to ~27% for depletion of exhaustible resources (oil, gas, minerals).	Fisher and Rothkopf (1989 and Mead (1979)	Raise price to producers	Direct, assets
Transfer of risk to Government	Governments assume some of the risk taken by energy producers through all kinds of measures.	Mills (2003)	Lower production's cost	Off-budget and indirect

In general to avoid overestimation, electricity reference prices rely on the LCOE from a combined-cycle gas turbine plant as a ceiling (Olejarnik 2013; Lin and Jiang 2011).

This methodology captures the support for end-users, which is the major part for fossil fuel energies, and doesn't take into consideration other types of subsidies such as industry development. This entails an underestimation of ES and their economic impact on the Government budget (Koplow 2009).

2.3.2 The Effective Rate of Assistance

The Effective Rate of Assistance (ERA) calculation considers local price direct and indirect effects. This consideration makes it practically difficult to apply because of the intensive required data such as the upstream industry of the estimated product (Plunkett et al. 1992; Anderson 1980). Originally, it derives from the effective rate of protection developed in 1960s. It measures net incentives for activities producing tradable goods.

ERA's formula is in Eqs. 4.2 and 4.3:

$$Net\ Subsidy\ Equivalent = Assisted\ Value\ Added - Unassisted\ Valued\ Added \tag{4.2}$$

$$ERA = \frac{Net\ Subsidy\ Equivalent}{Unassisted\ \ Value\ \ Added} \times 100 \tag{4.3}$$

Where:

- Assisted value added is the fully subsidised added value of an activity. It considers domestic pricing arrangements, export subsidies or taxes, local content schemes, production subsidies, quantitative import restrictions, tariffs, variable levies and voluntary export restraints. Moreover, it includes land, labour or capital returns.
- Unassisted value added representing real value of an output without any intervention.

2.3.3 Producer Subsidy Equivalent and Consumer Subsidy Equivalent

The Producer Subsidy Equivalent is the nominal cash allocated to local producers corresponding to the total support for a certain level of outputs, consumption and trade. Therefore, it focuses on the supply side and does not capture all subsidies. On the other hand, the Consumer Subsidy Equivalent (CSE) rather focuses on consumption and end-uses and is presented in Eq. 4.4 (Cahill and Legg 1990):

$$\begin{aligned} CSE = \sum \left(\text{domestic prices} - \text{international prices}\right) \times consumed\ quantity \\ + \text{direct financial payment to consumers} \end{aligned} \tag{4.4}$$

Where:

- Domestic prices are prices paid by consumers;
- International prices reflect the cost of energy including transportation and distribution costs;
- Direct financial payment to consumers are direct subsidies paid by the Government to consumers to afford access to energy.

2.3.4 The Pass-Through Approach

Equation 4.5 is another method for measuring the magnitude of energy subsidies developed by the International Monetary Fund (IMF), named the pass-through approach (IMF 2013).

$$P.T = \frac{\mathrm{Pr}(\mathrm{t}) - \mathrm{Pr}(\mathrm{t}-1)}{\mathrm{Pw}(\mathrm{t}) - \mathrm{Pw}(\mathrm{t}-1)} \tag{4.5}$$

Where:

- *Pw(t)* is the international price or the supply cost;
- *Pr(t)* is the actual retail price paid by consumers, including taxes.

Thus, PT factor reflects the changes in international prices for energy goods on retail prices in the local market. There are three possible cases:

- **PT** = 0, then prices are fixed or virtually fixed.
- **PT** < 1, then there is exemptions of subsidies or tax.
- **PT** ≥ 1, then there is full pass-through or no subsidies, meaning that all the fluctuations in the international prices of energy goods are reflected in the domestic market.

However, this methodology has some limitations since the indicator can be negative around an inversion of the trend in international prices; it is as well sensitive to the choice of start and end-dates; and it does not account for initial price levels.

2.4 *Effects*

ES effects have economic, social and environmental dimensions, connected to each other. Indeed, ES accompanied with other policies conditioning the supply and demand and protecting the environment affect primary marginal revenues, production and incomes. Subsequently, they affect the composition of production and the outputs related to each sector. Further, ES have direct and indirect effects on emissions and resource use causing other consequences on environmental damage. Hence, ES effects should be interpreted based on a holistic approach (Ogarenko and Hubacek 2013; Sdralevich et al. 2014).

2.4.1 Economic Effects

On the one hand, several studies have identified the high costs associated to ES and the appearance of economic efficiency losses.

Firstly, by lowering blindly end-use prices there is an augmentation in energy's utilisation. This causes a reduction in incentives designated for more efficient energy and technologies, which was the case of the former Soviet Union. Those technologies have a high investment cost comparing to conventional technologies. The subsidies targeting consumption may decrease energy suppliers' profits and their ability to invest in new infrastructure, causing severe energy shortages.

Moreover, direct subsidies in the form of grants and tax exemptions present a heavy burden on Government's budget especially when international prices are high. Price caps, a subsidy form, have led to physical shortages and have required costly administratively arrangements.

Additionally, the increase in energy use due to subsidised prices entails an augmentation of imports or a decrease in exports. This engenders a high dependency on other nations or a spread of smuggling fuels, the case in many African countries. This illegal trade causes budgetary costs for originating countries, and ability limitation to tax domestic consumption for receptor countries.

Specifically, electricity subsidies could present a heavy burden on the state budget and weaken public funds. Therefore, they limit the development on other sectors. Other problems might occur (Narula et al. 2012; USAID SARI 2004):

- Overconsumption and waste of electricity due to distorted prices;
- Equipment negligence, subverting production and limited innovation;
- High interest and focus on subsidising one kind of sources creating barriers to diversification and to private sectors to flourish;
- Lifeline rates poorly designed and can be serving political considerations leading to disastrous financial and environmental damages.

On the other hand, there are several economic advantages from energy subsidies. For instance, subsidies targeting producers will reduce charges on investors and participate in industrial development. The energy related services provided by the Government such as investment in infrastructure or public R&D represent a tool of improving the value chain of the energy sector and increasing related added-value. Moreover, the transfer of risks to the Government allows providing a safer and a more favourable environment for investors.

2.4.2 Social Effects

Social effects could be deduced based on the type of subsidy. For this matter, let's take into consideration the division consumer/producer subsidies.

Consumption subsidies allow:

- Providing an affordable and accessible energy;
- Promoting a switch from traditional, i.e. wood energy, to modern forms of energy, i.e. conventional or renewable.

With subsidies' policies, Governments aim also to improve the living conditions of people. An affordable energy allows indeed a creation of more productive activities either in rural or urban areas affecting thus the phenomenon of exodus. Unfortunately, in many developing economies the social benefits don't reach rural areas. It is the rich and high consumer who are most likely to benefit, leaving the poor in a worse situation since the costs of subsidies are shared by the whole population (United Nations Environment Programme and International Energy Agency 2002). As a matter of fact, the situation results on:

- The poor is unable to afford subsidised energy;
- The financial value to the poor is very low due to their modest consumption and price caps;
- The middle and high income classes get more advantages from ES.

In many cases, ES ended up in capital intensive projects causing, on the one hand, a displacement of communities or affecting the health of poor neighbours unable to move away. On the other hand, ES boosted improving conditions of power and infrastructure in neighbouring areas of projects investments. This reflects hence the contradictory effects of E.S.

2.4.3 Environmental Effects

The environmental effects are dependent on the type of subsidy and energy sources. ES to end-users lower the prices, increase the consumption, and cause therefore an augmentation of emissions and pollution (especially with the utilisation of conventional energy like oil). ES to producers, increase production and therefore raise pollution. However in some developing countries, ES for fuel lower deforestation phenomenon and carbon emissions, making the switch to modern forms (fuel and electricity) highly favourable. Moreover, subsidising renewable energies will avoid emissions and decrease deforestation.

With the increase of concerns lately about climate change, many research works have tried to solve the dilemma (Dipa et al. 2015): *"Is subsidy worthy or harmful for mitigating climate change?"* Many have concluded that fossil fuels contribute to higher GHG emissions. This was based on the observations about the removal of coal subsidies in OECD countries, which have generated important environmental benefits. Cert, subsidising renewable energies and energy efficiency initiatives will further decrease emissions. However, it requires high supports to make it competitive and therefore it negatively affects the Government's budget. Some types, such as biofuels or non-consideration PV panels recycling, might cause also severe damages on the natural resources. In conclusion, emissions have to be assessed during the whole life-cycle from production, to conversion, transportation and end-use (UNEP-DTIE 2008).

3 Renewable Energy Subsidies

3.1 Framework

Among the challenges encountered during the integration of RE, Governments need to (Been 2013):

- Adapt the energy balance;
- Implement policies which promote cost competitiveness and avoid windfall profits;
- Identify appropriate policy funding mechanisms;
- Ensure that decisions are made transparently and are accountable;
- Achieve wide-scale political willing and social acceptance;
- Map institutional discrepancies, policy implementation and uncertainty of decision making roles;
- Overcome bottleneck situations related to the infrastructure of conventional energy sources, long-term planning and funding and qualified human capacity.

Governments have then adapted different policies to promote and implement renewable energies.

RE policies go along legal, institutional and regulatory frameworks, are country-specific and inspired from international experiences.

3.2 Typology

Table 4.2 summarises Government interventions for RE development, where each type is divided into different forms alongside the energy supply chain.

4 Energy Subsidies Reforms

Abolishing ES might be complex and difficult because of their entrenchment in institutional barriers and lock-in mechanisms. Indeed, they generally entail economic rents for industrials and certain consumer classes who are the prime beneficiaries, offer incentives and make political actions.

Table 4.2 Government interventions for renewable energies

Government interventions	Type	Definitions/ Schemes	Sources
Direct financial transfers	Consumer subsidies	Given directly to consumers to encourage them switching from fossil fuel to RE, for e.g. through the acquisition of an equipment part of the installation to decrease investment cost.	Saidur et al. (2010)
	Feed-in tariffs (FiT) and power purchase agreements (PPAs)	FiTs offer investors in RE a preferential price, often guaranteed by long-term PPAs and grid access. FiT allows investors calculating the period to recoup their investments. Prices include profits as well.	
	Preferential credit	For many commercial or development banks, investments in RE projects entail technology and policy risks. Such institutions could offer low-cost credit lines, i.e. loans with lower interest rates, and partial risk guarantees handled by the Government. The Government encourages these institutions to offer preferential lending to RE project developers, for e.g. over 3 years grace period.	
	Production subsidies for equipment manufacturing	Capital grants or low-interest loans to RE equipment manufacturers decrease the cost of equipment production or help to expand manufacturing capacity.	
	Export subsidies	Could be direct grants or concessional loans, to encourage local manufacturers and other firms offering clean energy products and services.	
Preferential tax credits	Tax credits for consumption	Tax exemptions, could be a reduction from personal taxes, used to encourage consumers to adopt RE. This could be applied through electricity bill in case consumer has a RE installation.	Haas et al. (2011)
	Accelerated depreciation	Project developers could use higher depreciation rates on their RE assets and thus receive related tax breaks. In fact, it will lead to high deductions in the earlier years of the lifecycle of the RE power plant and later on investors could have higher profits.	
	Investment tax credits	Attract more foreign capital in RE. Income tax breaks offer investors the attraction of higher profits. Another form is perceived when the Government decrease taxes for an investor in order to invest further in RE projects.	
	Production tax credits	The credits, or generation-based incentives, are paid per kWh of electricity produced over the guaranteed power tariff. The amount paid is dependent on the actual amount of power produced. Then, there is an incentive for producers to generate more.	
	Excise duty rebates	Rebates on sales, royalties and other levies are targeted at increasing RE production or manufacturing RE capacity.	
	Export tax rebates	Like export subsidies, tax concessions could be used to encourage exports of RE products and services.	

Regulation	Grid connections	Access to the grid: One of the most difficult challenges for scaling-up RE infrastructure. Government could assure the availability of the grid and related reinforcement.	Toke (2007)
	Renewable Purchase Obligations (RPOs)	It represents a demand guarantee: a guarantee of ever-increasing demand for RE helps bringing prices down. In fact large consumers are obliged while purchasing electricity to assure that it is originated from RES.	
	Trading via RE certificates	Instruments promoting shares of RE used by a utility based on an integrated and efficient national or even cross border electricity grid. It consists on receiving a certificate when the producer has achieved RES objective; once electricity is sold, the producer could sell the certificate as a commodity.	
	Government procurement	Regulatory policies obligating the Government to procure more energy-efficient products or have more shares of RE. This is achieved through national strategies and engagement of the Government in international agreement, for e.g. Protocol of Kyoto.	
	Compulsory licensing of intellectual property	It ensures that companies have access to the best technologies. This will help promote and access to innovative RE technologies.	
Infrastructure support	Grid access	Extension of grid access could enable people living in rural areas to benefit from larger RE projects. The Government should then invest in electrifying the whole territory to assure investments in rural areas.	Sovacool (2009)
	Land acquisition and access to other natural resources	Infrastructure support offered to build RE generation capacity and local manufacturing bases or to promote exports.	
Investment and trade restrictions	Market access restrictions and investment measures	Regulations could prohibit foreign firms from participating as project developers in setting up RE generation capacity. Tariff barriers could also favour domestic equipment suppliers. This will help local small investors to survive and promote RE activities.	Menanteau et al. (2003)
	Quotas	A form of trade restriction promoting domestic production that has an economic impact on lightening the firm's budget to tax payers. Therefore, part of produced goods, i.e. RE technologies, should be injected in the local market to assure their utilisation and promote indirectly RE investments.	
	Technical standards	Restriction of imports by promoting domestic manufacturing technical standards	
	Local content requirements	The purpose is to progressively stimulate local industries to familiarise and create jobs	
Potential risks with subsidy schemes	Governments and stakeholders have to be aware of the risk that would be generated from undesirable effects of subsidies and programmes, and in case of non-transparency and ignorance of the participatory and consultancy approach.		Sovacool (2009)

4.1 Benefits and Challenges of Reforms

During the last years, ES reform received much attention internationally especially with the financial and economic crises. Many Governments believe that phasing out ES would be highly beneficial for their budgets. This occurs exclusively when subsidies are not really serving the objectives that they have been implemented for and causing economic, financial and environmental damages (Sovacool 2017; Sdralevich et al. 2014; UNEP-DTIE 2008).

With the continuous interest in green growth strategy, both developed and developing economies subsidising energy goods have been concerned with the reform of their energy subsidies. In the view of reducing GHG emissions and initiating green development, Governments have to examine environmentally harmful subsidies (EHS). The success of a reform is dependent on the implication of the Government, stakeholders and society. Analysts have identified the benefits and challenges of ES reform through research studies in (Von Moltke et al. 2004; Lin and Jiang 2011; Sdralevich et al. 2014).

On the one hand, the transformation of subsidies could result in:

- Reducing the intensive use of resources and thus polluting less;
- Increasing competitiveness by supporting other sectors;
- Making polluters pay for their pollution;
- Overcoming technological lock-in;
- Improving the cost-effectiveness of financial mechanisms by re-allocating budget.

On the other hand, people behaviours have become dependent on subsidies mechanisms[1] since goods and services are at low prices. Reforming ES would have to deal with the income distribution and social acceptance.

ES reform faces numerous challenges whether economic, institutional or political; known that in most cases the main barrier is not economic but rather political.

The lack of political will to reform subsidies could occur. This is due to the strong special interests and rent seeking behaviours. And then, it makes ES benefits concentrated in a small group not presenting the whole population, while the costs are spread within the population. Politicians fear the change and social disruption, which was the case in India, Iran, Malaysia and Nigeria. The increase in energy prices engendered an increase in related goods and even people losing their jobs.

Institutional constraints are due to either the institution benefits from ES or the lack of vision. ES mechanisms are highly connected with other financial policies entailing holistic transformation of the economy and finance of a country. Worthwhile, the lack of transparency, information and data represents a major barrier (Sdralevich et al. 2014).

[1] For e.g. low subsidised fuel prices, in Middle Eastern countries, have resulted in the increase of car purchases and utilisation.

Eliminating ES without a clear planning will lead to a decline in households' welfare due to the increase of energy, related goods and services prices. Furthermore, eliminating ES has different generated effects in the short and long runs, as follow:

- ES reform considerations in the short-run: In the case of an augmentation of prices, the poor classes won't be able to pay for basic needs such as food. This situation was not captured during the modelling made by OECD in (IEA, World Bank, OPEC, and OECD 2010) using a Computable General Equilibrium (CGE) model. Contrary, OECD found income gains. Moreover, the removal of ES can also affect industrial competitiveness because the price of energy as input will rise. Furthermore, effects on profit margins engender an inability to secure finding and to plan for long-term, especially the case for industries with high energy intensity and competition. In addition, the removal of ES decreases demand, which affects as well employment. However, impacts on Government budget are seen annually impacting positively budget deficits.
- ES reform considerations in the long-run: The reform might lead to an improvement of the economy's growth, deflation of energy prices. This situation could be reached if during the medium term there isn't any increase in workers' wages and the increase in prices is rather seen as an augmentation of taxes indirectly (Sovacool 2017; IEA, World Bank, OPEC, and OECD 2010). The removal impacts as well the environment, since energy will be used more efficiently generating a decrease in GHG emissions and pollution in general. However, there is a high risk of failure of the reform on the long-run because of poor management of saved Government interventions.

4.2 Benchmarking of Reform Methodologies

4.2.1 International Monetary Fund Method

Based on the IMF research and case studies (Von Moltke et al. 2004; IMF 2013; Been 2013) about reforming ES in numerous developed and developing countries, a successful reform could be divided into two main parts:

- Identification of barriers to reform;
- Design of a reform strategy.

Identification of Barriers to Reform The barriers encountered to reform ES is country-specific. However, there are some common obstacles in most of the cases that decision makers should take into consideration. These obstacles are primarily related to social opposition (Fattouh and El-Katiri 2013), due to:

- The lack of information to the public renders the population unaware of the size of fiscal costs that the Government is covering and counter-effects of subsidies on poverty;

- The lack of Government credibility and transparency because of corruption make people opposed to the reform since they ignore and are suspicious on how the savings from ES reform will be spent;
- The short-run social impact on low income classes will increase their poverty due to the increase of fuel prices;
- The periods of low economic growth and unstable prices favour oppositions. Therefore, decision makers should consider the timing of reform to be able to recompense the increase in prices, e.g. reforming ES when rising household incomes.

In an economic perspective, the Government should be aware while reforming ES of fuel inflation effects in the short-run, international volatile oil prices and energy-intensive sectors suffering from a loss of competitiveness.

Finally, except population's resistance to the increase in energy prices, there are oppositions from interest groups such as politically vocal groups, labour unions, middle/upper class, losers from the reforms such as State-Owned Enterprises in the energy sector or exporters (Painuly 2001).

Design of a Reform Strategy In order to overcome the barriers mentioned above and to successfully implement a reform of ES, IMF has developed a list of key ingredients that decision makers should follow to trace a clear strategy for the short and long-runs described in (IMF 2013). To summarise, setting up a price mechanism requires four main steps (De Broeck and Kpodar 2014):

(i) Relating the retail price to import costs, distribution costs and taxes;
(ii) Specifying the time step to update prices;
(iii) Establishing a price smoothing mechanism as a periodic lagged rate of price increase;
(iv) Specifying the smoothing mechanism and creating an authority in charge.

4.2.2 Organisation for Economic Cooperation and Development and World Bank Methods

Both the Organisation for Economic Cooperation and Development (OECD) and the World Bank (WB) have developed various tools, for instance quick-scan and adapted models, to estimate the impact of subsidies removal on the economic and environmental levels. Commonly, they relied on decision trees (OECD 2013). Decision trees are support tools that use a tree-like graph for decisions. They identify the possible consequences of decisions through providing analytical frameworks to understand the effectiveness of a subsidy scheme. They do not measure the subsidy's scale or impacts of removal on political and economic spheres. We could find OECD checklist, OECD integrated assessment framework and World Bank checklist, as quick-scan methods. Within checklists, each answer launches a chain of continuous consequences until a final decision is reached.

Conversely, models, such as OECD ENV-linkages, are used to assess and quantify the effects of ES on environmental, economic and social spheres. They follow either an economic or econometric vision and have been developed on a local, regional or global scale. They point out the combination of demand and supply elasticities and energy prices (Château et al. 2014).

For this matter while analysing electricity subsidies, Sect. 5 touched upon Energy Systems Models (ESM) as a tool of analysing and forecasting energy mechanisms based on a holistic approach considering economic, econometric and technological perspectives.

5 Case Study: Electricity Subsidies in Tunisia

The Government has been since the 1960s supporting the industrial sector and assuring an affordable access to the energy for the Nation. The Government intervention is practiced through the fixed pricing policy assuring acceptable economic and social standards. However, in the twenty-first century the country has known an energy deficit due to the decline of national fossil resources and the incremental increase of demand. This deficit has affected the financial situation and caused a budget deficit (Dhakouani et al. 2017).

Precisely, electricity in Tunisia is produced at 97% by natural gas (NG) in 2017; and most of NG demand is reflected through electricity consumption. Roughly speaking, over 50% of electricity costs is subsidised for different end-users. Following the engagement of Tunisia to the COP21 in 2015 for climate change reduction, the Government launched a new strategy to assure a sustainable energy transition. Amongst major axes, the integration of renewable energies for the production of electricity is reflected through the national plan intending to reach 30% of Renewable Energy Sources (RES) in 2030 in the electricity mix. Other climate change engagements consist on decreasing carbon intensity by 41% comparing with the rates in 2010 and decreasing primary energy demand by 30% in comparison with the actual trend scenario. However, the financial situation plays a major role in postponing renewable projects implementation due to their high costs and the lack of financial resources (Dhakouani 2018).

A reform of the pricing mechanism of energy and specifically electricity could be of practical value in light of minimising the energy budget deficit. This reform should also target the maximisation of renewable energies integration. Nevertheless, the investment cost of renewable technologies is not competitive comparing to conventional technologies. On the one hand, costs could be treated with a long-term cost-based optimisation of the supply, which appeals technologies competitiveness. On the other hand, electricity pricing—*subsidies*—could be treated following one of the reform methodologies introduced in Sect. 4.

Analysing the case study of the Tunisian power system entails the following steps:

(i) Identification of electricity system subsidies in Tunisia;
(ii) Description of undesirable subsidies effects;
(iii) Measurement of subsidies;
(iv) Identification of the reform methodology;
(v) Optimisation of electricity costs produced;
(vi) Integration of the smoothing mechanism and reshaping electricity demand;
(vii) Reconfiguration of technologies competitiveness.

5.1 Applicable Definition

In the field of electricity, subsidies target principally the consumer since the market follows a vertical integrated monopoly. However, the objectives of subsidising power system components differ:

- Electricity subsidies have been introduced to offer to end-users lower prices than supply costs. These subsidies are the most important, proportional to the consumption of electricity and are variable.
- Electrification subsidies is introduced to all end-users. These subsidies are at fixed prices.
- Electricity produced by RES is subsidised since 2010, through a national programme targeting self-production regime using solar roofs, on investment.

Referring to definitions in Box 4.1, IMF definition is the most applicable to the case of Tunisia. It allows capturing consumer-based subsidies in function of electricity consumption, which is the predominant part in electricity subsidies.

5.2 Types of Electricity Subsidies in Tunisia

Taking into consideration the typology introduced in Sect. 1, Table 4.3 exhibits power system subsidies in Tunisia.

In regard to RE subsidies, Fig. 4.1 shows the different Government interventions (Tunisian Parliament 2015, 2016, 2017).

5.3 Measurement: Relating Costs to Prices

Measurement of electricity subsidies in Tunisia is assessed referring to Sect. 2.3. Firstly, ERA cannot be applied since it considers local price direct and indirect effects. This involves other related sectors than electricity which are out of the scope of this work. A part, the intensiveness of data could increase error rates and impact

Table 4.3 Government interventions in the Tunisian power system

Government interventions	Case schemes	Effects on prices
Tax expenditures	Electricity produced by the state-owner enterprise Société Tunisienne de l'Electricité et du Gaz (STEG) either from conventional or renewable technologies, and distributed for final consumption.	Lower consumer's price
Government revenue foregone	Government allows using land by STEG or independent power producer (IPP) for the implementation of power plants.	Lower production's cost
	The contract between STEG and IPP is regulated considering the notion of depletable assets	
Regulation of the energy sector	Price control of electricity	Lower price to consumers
	Market-access restrictions and preferential planning consent	–
Energy-related services provided by Government at less than full cost	Direct investment energy infrastructure: Transmission and distribution of the grid	Lower production's cost
	Collaboration with internal resources in public institutions instead of a full dependency on private consulting firms	Lower production's cost
Failure to impose external costs	Even though emissions are regulated and the excess is penalised, the Government is not applying environmental externality costs.	Lower consumer's price
	The Government by almost fixing electricity prices is handling price volatility costs.	Lower consumer's price
Transfer of risk to Government	The Government assumes a part of risks instead of IPPs, for e.g. exchange rate risks	Lower production's cost

insights. Secondly, even though CSE focuses on consumption and end-uses subsidies which are the predominant in the case of Tunisia, the direct financial payments to consumers are not applicable. Thirdly, P-T approach does not quantify subsidies but rather measures their magnitude. In regard to the *price gap approach*, this method captures principally the support for end-users based on the LCOE as a reference price. In addition, the availability of data and its extensiveness represent a major feature for its application in Tunisia.

Considering an integration of 30% RES by 2030 in the electricity production would be processed through a cost-based modelling— LCOE. The *price-gap approach* allows then relating electricity subsidies to supply costs through supply shares, demand and prices. Moreover, using the *price-gap approach* will allow quantifying subsidies related to consumption.

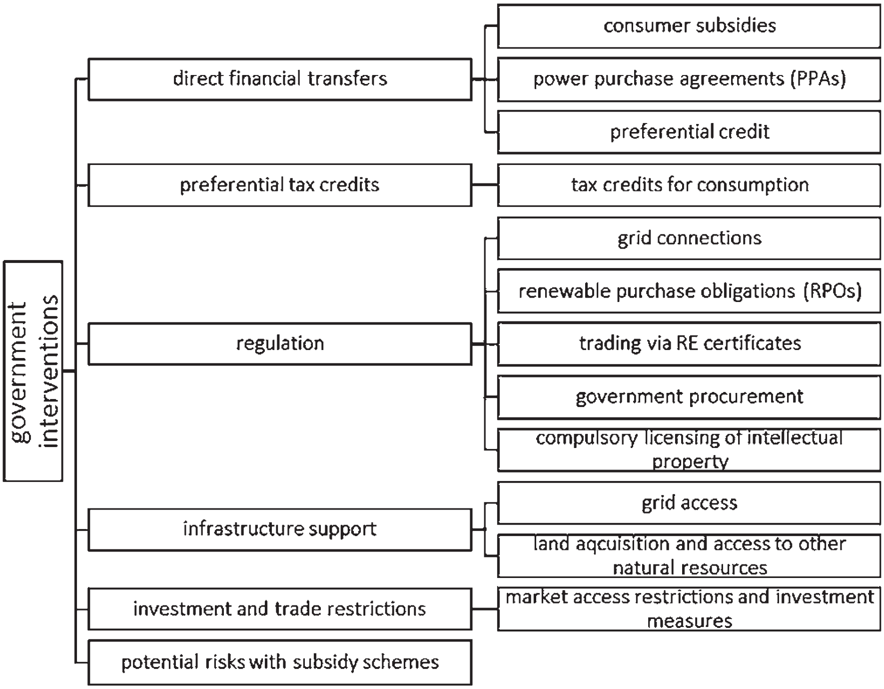

Fig. 4.1 RE subsidies in Tunisia

5.4 Reforming Electricity System Subsidies

In order to identify subsidies requiring a reform, it is essential to study the different effects engendered by subsidies. Following, Table 4.4 depicts the negative effects of electricity subsidies. RE subsidies are very limited compared to conventional electricity subsidies; then they are not included. Moreover, electrification subsidies have allowed reaching high rates of access to electricity above 99% in rural and urban areas by 2017, and have reached the objective that have been implemented for: *access to electricity* (Société tunisienne de l'électricité et du gaz*)*.

In regard to the identification of the most suitable methodology for the reform of electricity subsidies, this Chapter considers the IMF methodology as the most appropriate since it is based on the *price-gap approach.* Integrated with other methodologies, it allows treating different issues related to renewable energies integration in Tunisia, such as linking supply cost with energy subsidies. Indeed, the *price gap-approach* and the related method of reform could be modelled using an econometric model or integrated in a cost-based model to offering partial equilibrium features.

Per contra, OECD checklist targets only environmentally harmful energy subsidies. It is noticeable in Table 4.4 that undesirable economic effects are the main ones. In addition, OECD integrated assessment framework is a qualitative method

Table 4.4 Undesirable effects of electricity subsidies in Tunisia

Types	Effects
Economic	Augmentation in electricity and NG utilisation;
	Energy balance deficit;
	Deficit in energy Government budget;
	Decrease in tax revenues due to international prices fluctuations;
	Augmentation of NG imports and decrease of energy security;
	Reduction in incentives designated to more efficient energy;
	Decrease of investments in economically more attractive technologies;
	Decrease in STEG profits and debt ratio;
	Decrease of public infrastructure investment.
Social	High consumers benefitting most;
	Economic activities benefitting;
	Low income classes not affording subsidised prices.
Environmental	Augmentation of emissions and pollution;
	Decrease of opportunity to access to green funds.

and focuses on the linkages of energy and other sectors. Considering that the scope of this work is the electricity system, this method wont' satisfy the objectives to reach. In regard to the World Bank checklist, this method is based on a cost-effectiveness analysis and comparison of alternatives which is out of the scope of this work. Finally, with respect to developed models treating energy subsidies, the choice of the model depends on other technical, economic and regulatory criteria to assure a high integration of renewable energies too.

5.5 Hybrid Modelling of the Power System

The developed countries have been using Energy Systems Modeling (ESM) (Kern and Smith 2008) since the 1950s for energy transitions. This has led to a high number of approaches and types. The different types of analyses which were primarily developed target the supply side of an energy system, where the objective was to meet a given exogenous energy demand (Bhattacharyya 2011). Due to the oil crisis in the 1970s, demand side energy systems analyses have appeared and have kept evolving through years, leading to forecasting approaches, and later on translated to top-down models. Meanwhile, supply-oriented focus has kept evolving and has led to integrated bottom-up models which are technologically oriented to identify the needed investments or to operate short-term solutions (Hoffman and Jorgenson 1977; Hoffman and Wood 1976). Lastly, hybrid models, i.e. a combination of bottom-up and top-down models, have resulted in better insights for decision makers (Gargiulo and Gallachóir 2013; Bhattacharyya and Timilsina 2009). Considering the review articles on ESM such as (Urban et al. 2007), the choice of the appropriate modelling framework is identified from the context and the challenges depicted in major developing countries. In fact, it has been proven that the problem of optimally designing the electricity system in such a way as to match the demand with available resources and supply technologies can be solved by a bottom-up optimisation modelling framework. Given the easy access to the source code, the different developed versions, and the accessibility to manuals, the advanced version of *Open Source energy MOdelling SYStem* (OSeMOSYS) has been chosen to model the power system (Dhakouani et al. 2017; Howells et al. 2011). OSeMOSYS is originally a bottom-up, dynamic and linear optimisation model applied to the integrated assessment and energy planning.

5.5.1 Advanced Version of "OSeMOSYS"

Long-Term Optimisation of Electricity Supply OSeMOSYS aims to determine the lowest net present cost of an energy system to meet given demands and constraints. The original code of OSeMOSYS consists of several blocks of functionality, computing balances for costs, storage, capacity adequacy, energy balances and emissions. Recent works added blocks of functionality for reserve capacity dispatch and costs of flexible operation, in order to refine the analysis of short-term implications due to the penetration of intermittent RES (Welsch et al. 2015; Gardumi 2016).

Long-Term Simulation of Electricity Demand In order to present insights and to analyse the impacts of electricity end-users subsidies on the integration of renewable energies in the electricity mix, the integrated functionality block in the core code of OSeMOSYS related to electricity demand is appealed. The variation of prices using an automated smoothing mechanism impacts the evolution of demand. Thus, this version allows analysing the impact of subsidies on the demand and on the supply sides.

In regard to electricity demand modelling, the advanced version of OSeMOSYS relied on two approaches, i.e. decomposition and econometric.

Econometric Approach

The econometric approach allows connecting the demand to prices. It is a standard quantitative approach for economic analysis that establishes a relationship between the dependent variables (prices) and independent variables (income or economic growth rates) by static or dynamic analysis of historical data (Ryan and Plourde 2009; Bhattacharyya and Timilsina 2010; Momani 2013). The log-linear form of econometric specifications provides imbedded estimation of price and income elasticities and is better suited to energy demand than a simple linear specification (Bhattacharyya 2011). The advanced version of OSeMOSYS relies on the dynamic log-linear equation of energy demand in function of prices and income/ economic growth rates variables, developed by *Cobb Douglas* function in Eq. 4.6. The double-log regression model is a standard approach in the energy consumption studies (Madlener et al. 2011; Zaman et al. 2015).

Considering a time period of 1 year, demand block of OSeMOSYS stands on Eq. 4.6:

$$lnDy = \ln \mathrm{a} + \mathrm{b} * \ln \mathrm{GDPy} + \mathrm{c} * \ln Py + \mathrm{d} * lnDy - 1 \quad (4.6)$$

Where:

- *y:* year
- GDP_y/GNI_y: gross domestic production per capita or gross national income per capita during the year y
- D_y: energy demand during the year y; D_{y-1}: energy demand during the previous year
- P_y: price of the energy during the year y
- *a:* scaling factor
- *b:* short-term GDP or GNI elasticity
- *c:* short-term price elasticity
- *d:* lagged-demand coefficient

The embedded prediction of prices during a year is processed using IMF method (Kaltenbacher et al. 2008) and presented in Eq. 4.7:

$$\ln P_y = (\mathrm{y} - \mathrm{yo}) * \ln(1 + \mathrm{s}) + \ln \mathrm{P}_{\mathrm{y0}} \quad (4.7)$$

Where:

- y_0: the start-up year of modelling;
- P_{y0}: the price in the start-up year;
- P_y: the price in the year y; and P_{y-1}: the price in the previous y;
- *s:* the smoothing band. It is the percentage of subsidies decrease.

Decomposition Approach

The repartition of electricity demand by sector is appealed since subsidies differ by end-users. Moreover, demand types are differently sensitive to the smoothing band; depending on their elasticities to prices. The disaggregation follows Eq. 4.8:

$$\begin{aligned} Total\ demand &= low\ voltage\ residential\ demand \\ &+ (High + medium + low\ voltages)\ industry\ demand \\ &+ (High + medium + low\ voltages)\ services\ demand \\ &+ (High + medium + low\ voltages)\ agriculture\ demand \end{aligned} \quad (4.8)$$

Where:

- *Low voltage residential demand:* residential electricity demand. Generally residential demand is associated to low voltage power.
- *High, medium and low voltages industry demand:* electricity demand by voltage type in the industry sector
- *High, medium and low voltages services demand:* electricity demand by voltage type in the service sector
- *High, medium and low voltages agriculture demand:* electricity demand by voltage type in the agriculture sector

The short-run price and income elasticities, the coefficients of the regression, the scaling factor (intercept), logarithmic GDP or GNI per capita factor, logarithmic price factor, and logarithmic lagged demand factor are obtained from (Dhakouani 2018).

5.5.2 Main Input Data

Main input data of the model, not scenario dependent, are from (Dhakouani et al. 2017; Dhakouani 2018) and are summarised in Table 4.5. These parameters cover technical, economic and environmental characteristics of modelled technologies. The principal characteristics of considered scenarios are taken from (Dhakouani et al. 2017) and are related to the energy transition objectives, where the Business As Usual (BAU) scenario and RE scenario target respectively 5% and 30% of RES penetration by 2030 in the electricity mix. The rate of 5% of RES represents the natural technological integration. The 30% of RES represents the national objective of energy transition. The time horizon of modelling is from 2010 to 2030.

5.6 Electricity Subsidies vs. RES Penetration

In order to promote sustainable development and RE penetration in the power system, this modelling proposes to replace eliminated variable consumer (end-users) subsidies by production subsidies. As demonstrated in Sect. 4, production subsidies are more beneficial than consumer subsidies since they are targeted, on-budget and explicit. Moreover, these subsidies aid the industry development. To align with the energy transition, production subsidies will be targeted to promote sustainable and renewable technologies investments.

The *injection* of eliminated electricity subsidies on renewable technologies investments will lower investment costs of renewable technologies. Since LCOE from RES is primarily impacted by investment costs, subsidising renewable technologies will render these technologies more competitive. The *injection* reflects an incentive mechanism to promote RES penetration.

Table 4.5 Main input data

		Conventional technology[b]		Renewable technology							
		fuel fired Steam PP	CCGT	OCGT Large	OCGT Small	Wind	Cen PV	Dec PV	CSP	Hydro	PSH
Parameters[a]	*Units*										
Capital cost	USD/kW	220.5	200.9	705.0	428.0	1523.8	3312.8	5114.5	9800	1628.0	2618
Variable costs	M-USD/PJ	0.0	0.4	0.7	0.0	0.1	0.1	0.0	1.24	0.0	3.85
Fixed costs	USD/kW	21.0	12.1	20.0	15.0	12.5	29.0	29.0	67.26	14.4	18.27
Availability factor	%	91.8	94.9	97.0	94.3	97.5	99.0	99.0	96.0	91.0	92.0
Life cycle	Years	37	28	30	45	20	25	25	30	40	40
Efficiency	%	36.36	44.84	31.85	23.87	100.00	100.00	100.00	100.00	100.00	90.00
Unitary cost of the starts	USD/MW	58.16	53.32	47.86	29.08	_	_	_	90	_	
Ramping rate	MW/min	8	11	15	10	_	_	_	17	_	15
Minimum technical load	%	37.3	41.2	6.6	27.9	0.0	0.0	0.0	1	0.0	6.6
Max prim. Upward reserve	%	20.0	14.0	13.0	12.0	0.0	0.0	0.0	20.0	0.0	13.0
Max prim. Downward reserve	%	20.0	14.0	13.0	12.0	5.0	5.0	5.0	20.0	5.0	13.0
Max sec. upward reserve	%	12.0	6.0	70.0	75.0	0.0	0.0	0.0	60.0	0.0	70.0
Max sec. downward reserve	%	12.0	6.0	70.0	75.0	100.0	100.0	100.0	40.0	100.0	70.0
CO_2 generation	ton/PJ	1.93	1.46	2.38	2.38	0.00	0.00	0.00	0.00	0.00	2.38
NOx generation	10^{-3} ton/PJ	9.36	6.84	10.44	10.44	0.00	0.00	0.00	0.00	0.00	10.44

Reported from Dhakouani et al. (2017)

[a]Dashed cells: not applicable, no data available, out of research scope / All data is relative to 2010 – some parameters are evolving during the time horizon

[b]Conventional technologies characteristics where primarily extracted from the existing generating capacities. This data might be different from data sheets presented by manufacturers

Based on literature, the applicable smoothing mechanism bands in the energy sector and specifically electricity are 3%, 5% or 7% (IMF 2013; Sdralevich et al. 2014; Hanieh 2015). It has been demonstrated that greater smoothing mechanism values could generate a deterioration of the demand.

Due to the sensitivity of residential electricity demand to prices in Tunisia, the increase in prices through the application of above mentioned rates could lead to a deterioration of the demand — applied without any direct incentives to consumers. Based on research works elaborated in (Dhakouani 2018), a smoothing mechanism band for the residential sector of 0.24% annually will be applied. It has been demonstrated that this band allows a healthy growth of residential electricity demand. A smoothing mechanism band of 3% annually will be applied to the economic sectors, i.e. services, agriculture and industry, since they are less elastic to prices. Actually, economic sectors are more sensitive to GDP. Applying a 7% smoothing band to economic activities sectors has already resulted to an ill-conditioning and instability of the model. Moreover, eliminated energy subsidies in case of 5% smoothing band has much increased renewable technologies investments above 70% which is illogic for the considered time horizon.

Then, the *injection* of eliminated subsidies followed these hypotheses:

- A smoothing mechanism of 0.24% for residential sector;
- A smoothing mechanism of 3% for economic activities sectors.

Simulations included the application of hypotheses to:

- BAU scenario;
- RE scenario;
- No scenario: The power system without any scenario targeting a RES penetration rate. In other words, the constraint of achieving a certain rate of RES penetration was released and technologies were *freely* competing.

The results of simulations of the Tunisian power system, using the advanced version of OSeMOSYS, point out the impact of *injection* and are summarised in Figs. 4.2 and 4.3. Presented results are supply oriented showing the capacity shares evolution from 2010 to 2030 of the power system and the electricity mix in 2030.

As displayed in Fig. 4.2, the evolution of demand installed capacities is varying in the BAU, RE and No scenarios, achieving respectively by 2030, 8 GW, 11 GW and 12 GW.

The BAU scenario is characterised with high rates of conventional technologies because of the constraint limiting RES penetration to 5% even though renewable technologies are subsidised. Referring to Table 4.6, the BAU scenario achieved a total discount cost for the whole time horizon of 12.58 billion USD. In fact with subsidised investments of RE technologies, the limit of 5% of RES penetration represents a constraint that higher costs.

The low rate of total installed capacities is due to the elevated capacities of invested conventional technologies, their high availability factors and efficiency rates, referring to Table 4.5. By 2030, electricity demand would be satisfied at 70% from combined cycle (CCGT) because of its high efficiency as shown in Fig. 4.3a.

Gaz Turbines (OCGT) are primarily used to respond to the demand variation. Pumping Storage Hydro (PSH) represents 11% of electricity generation in 2030 since it allows responding to load changes by smoothing the load curve. PSH has originally a high investment cost, subsidising such investment would higher its chances to be more competitive independently from RES penetration.

In Fig. 4.2b, OCGT are more installed than CCGT even though their efficiency is lower. This is explained by their short-term characteristics — ramping characteristics as displayed in Table 4.5. OCGT are able to respond to quick variation either caused by the RES intermittency, especially wind participating at 18% in 2030, or the load curve variation. The highest share amongst renewable technologies is Centralised Photovoltaic because of the matching between generation production and the daily demand profile, where the summer peak is the most important in Tunisia. The integration of RES has led to a higher utilisation of PSH installed capacities than in the BAU scenario, as exposed in Fig. 4.3b. Where PSH is appealed to respond to RES intermittency and load curve changes. The RE scenario even though had 3 GW higher installed capacity, the subsidised capital costs of renewable technologies allowed decreasing the total discounted costs, reaching thus 12.53 billion USD. By 2030, primarily *renewable electricity* will be composed of 18% wind energy and 11% from Centralised PV.

The released scenario has led to high rates of renewable installed capacities by 2030 as shown in Fig. 4.2c. This is due to not constraining RES penetration and subsidising related investments. In fact, the model resulted in high investments in RE technologies, around 6 GW since they are becoming more competitive. However, due to their intermittency, the model should assure back-up conventional technologies for power system flexibility. Therefore, rates of 25% and 19% of the electricity mix were satisfied respectively by CCGTs and OCGTs in 2030 as displayed in Fig. 4.3c. By 2030, 50% of the electricity demand is satisfied by renewable technologies. It is noticeable that CSP by the end of the modelled period is invested, differently from the BAU and RE scenarios. Due to its flexibility in comparison with other renewable technologies, it will participate with 3% to electricity demand satisfaction. The integration of CSP has impacted PSH investment and utilisation, falling down to 350 MW in 2030. Subsidising RE investments without imposing a long-term objective to achieve allowed decreasing costs to 12.42 billion USD from 2010 till 2030.

In regard to the BAU and RE scenarios crossed with smoothing bands hypotheses, from 2010 to 2030 simulations have resulted respectively in 2.13 kton CO_2 and 1.92 kton CO_2. Accumulated NO_x passed respectively from 9.45 ton to 8.38 ton. It is remarkable that the RES penetration has impacted the decrease of NO_x emissions more than CO_2 emissions. This is due to the types of conventional technologies invested to respond to RES intermittency, i.e. OCGTs, and PSH— see Table 4.5. The lowest levels of emissions registered correspond to 50% of RES penetration, 1.77 kton CO_2 and 7.68 ton NO_x. Independently from the shares of conventional technologies types, CO_2 and NO_x emissions are proportional to the RES penetration rates. Referring to the agreements "Intended Nationally Determined Contributions", that the Tunisian Government has signed during the COP21, the RE scenario will

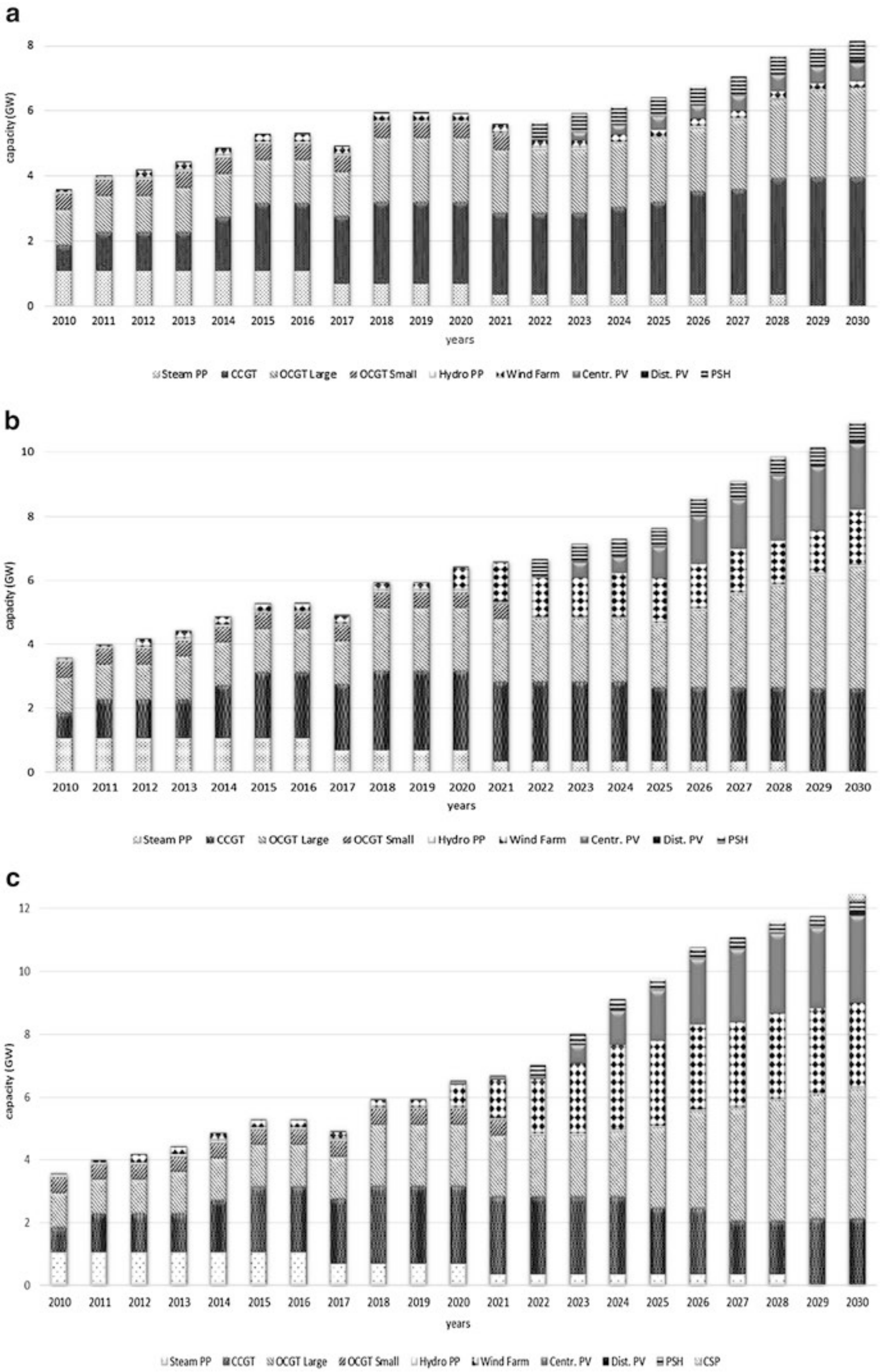

Fig. 4.2 Capacity shares evolution (**a**) BAU scenario; (**b**) RE scenario; (**c**) No scenario

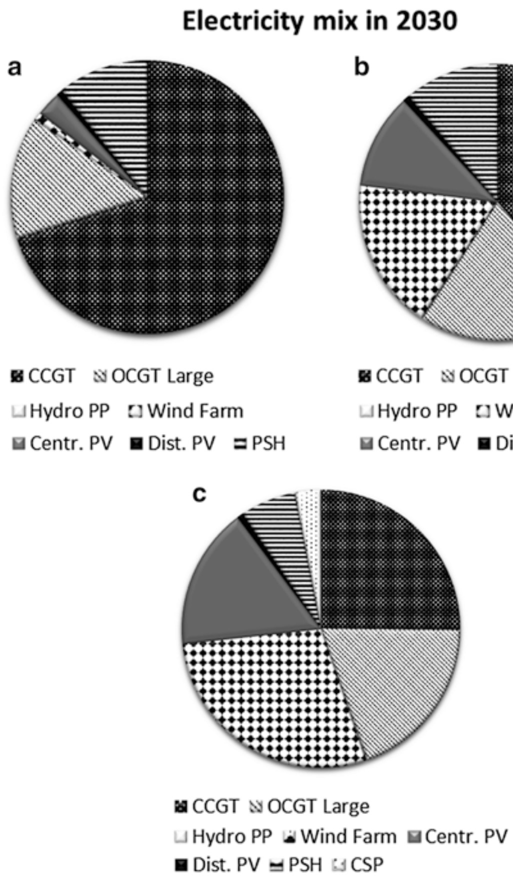

Fig. 4.3 Electricity mix by 2030 (**a**) BAU scenario (**b**) RE scenario (**c**) No scenario

Table 4.6 Total discounted costs – Subsidised RE technologies

	Cost (billion USD 2010)
BAU scenario	12.58
RE scenario	12.53
No scenario	12.42

highly contribute to achieving the target of reduction of carbon intensity to 41% compared to 2010, alongside changes within industry and transport sectors. It's important to mention that in 2010, Tunisia has reached 0.541 ton equivalent CO_2 per 1000TND expenditure. National efforts and INDC target to achieve 0.320 ton equivalent CO_2 per 1000TND expenditure by 2030 (Boisgibault 2015). Based on the hypothesis of emission penalty (3.3USD/tCO2), the impact on total emissions, total discounted costs and supply shares would have changed in function of emission penalties. Higher penalties of emissions would definitely increase the chances of having a supply share rich in terms of renewable technologies.

Finally, it is important to mention that the number of accumulated direct jobs created has reached 9153 if 50% of RES penetration was achieved by 2030. The identification of jobs could be simulated using the developed add-on of job creation introduced in (Dhakouani et al. 2017).

5.7 *Electricity Subsidies Reform Policy*

After all, the compound smoothing mechanism, i.e. 0.24% for residential sector and 3% for economic sectors activities applied to the advanced version of OSeMOSYS without imposing a RE objective, has lowered costs by 0.16 billion USD, in comparison with the BAU scenario, and allowed an integration of 50% of RES in the electricity mix by 2030. Injecting eliminated end-users electricity subsidies for subsidising renewable technologies investments has highly improved the competitiveness of renewable technologies. It is important to mention that contrary to conventional technologies where the LCOE is primarily impacted by fuel costs, generally renewable technologies has a high LCOE due to investment costs. In addition, subsidising RE technologies has generated a decrease in emissions. The effect of applying high penalties on emissions is reciprocal to subsidising RE investments.

The advanced version of OSEMOSYS has allowed presenting hybrid insights on the evolution of the power system in Tunisia. The balance of the supply and demand is mainly based on the connection between costs and pricing.

In fact, the Government is just targeting and orienting subsidies while i) decreasing end-users electricity subsidies at a rate that won't impact electricity demand evolution and ii) injecting eliminated subsidies into renewable technologies investments. Subsidies will be direct, for e.g. under the form of a financial contribution for producers. Yet, producers are not only limited to the field of renewable energies. Producers receiving renewable energies subsidies might be local investors in renewable energies projects, manufacturers of renewable technologies components, any other industrial willing to integrate renewable technologies to satisfy its needs in electricity consumption, or even within households for self-consumption (e.g. solar roofs). Through this mechanism, decision makers will avoid non-targeted and indirect electricity subsidies and will assure targeted and direct energy subsidies; switching then from harmful to beneficial incentive mechanisms. Moreover, the development of this field would eventually have social positive impacts such the creation of employment. Additionally, subsidising renewable technologies investments will higher the supply of these technologies because of an increase in renewable technologies demand. Referring to the market law, this will cause naturally a further decrease in the market price. When the market achieve a certain maturity, the Government could gradually eliminate even beneficial subsidies oriented to renewable technologies. Other long-term benefits that could be observed from this reform are the improvement of economic growth and energy security.

Finally, in order to avoid the aftermath of political instability from the switch of electricity subsidies, it should be appropriate to (i) identify and settle clear detailed objectives of an energy strategy, (ii) clarify public private partnerships to share risks and, (iii) assure social acceptance.

6 Conclusions

This chapter focuses on one of the major barriers of the integration of renewable energies in numerous developing countries: *energy subsidies*. Firstly, the literature review carried about energy subsidies, i.e. definitions, typology, measurement methods and effects, has shown that international organisations that have mostly brought this topic on the table. However, the notion of energy subsidies has differed. Therefore, different definitions were found which resulted in different typologies and methods of measurement. It is noteworthy that the price-gap approach is the mostly applied approach to quantify energy subsidies due to its simplicity, data extensiveness and relating supply cost to market price and retail prices. In addition, a special focus has been given to renewable energies subsidies. Based on the observation about the deviation of energy subsidies from the objectives that they have been settled for, the benefits, challenges and methodologies for reforming harmful energy subsidies have been reviewed. Significantly, a holistic approach for modelling an energy system taking into consideration the supply and demand would present useful insights to decision makers for energy transition. Energy subsidies and renewable energies are then introduced in a macro level based on the supply/demand equilibria of the power system.

Based on the context characterised by an energy budget deficit due to end-users electricity subsidies and an energy strategy targeting 30% of renewable energies by 2030, while it is currently at 3% (2019), the power system of Tunisia has been considered as a case study. The overview displays the applicable energy subsidies definition, the different Government interventions in terms of electricity, electrification and RE subsidies. To present insights on the power system reform, the advanced version of OSeMOSYS has been used as a tool of an integrated modelling. This version is a hybrid model, i.e. bottom-up with ends-users partial equilibrium based on decomposition and econometric approaches. The pricing system follows the smoothing mechanism approach developed by IMF to eliminate gradually subsidies. The decomposition approach pointed out separately economic sectors and residential sector, and voltage types.

A consideration of a smoothing mechanism of 0.24% for residential sector and 3% smoothing mechanism annually for economic activities sectors injected in renewable technologies investments as direct subsidies allowed achieving naturally 50% of renewable energies integration by 2030 and decreasing emissions.

Switching from end-users subsidies to production subsidies with a clear planning on a long-term perspective allows decisions makers to achieve high RES penetration, decrease emissions, diminish energy budget deficit and assure a sustainable energy transition.

References

Anderson K (1980) The political market for government assistance to Australian manufacturing industries. Econ Rec 56(153):132–144

Been H (2013) Meeting renewable energy targets: global lessons from the road to implementation. World Wide Fund Nat, p. 82

Benjamin K. Sovacool, (2009) The importance of comprehensiveness in renewable electricity and energy-efficiency policy. Energy Policy 37 (4):1529–1541

Bhattacharyya SC (2011) Understanding and analysing energy demand. In: Energy economics. Springer, London, pp 41–76

Bhattacharyya SC, Timilsina GR (2009) Energy demand models for policy formulation: a comparative study of energy demand models. Social Science Research Network, Rochester, NY, SSRN Scholarly Paper ID 1368072

Bhattacharyya SC, Timilsina GR (2010) Modelling energy demand of developing countries: are the specific features adequately captured? Energy Policy 38(4):1979–1990

Boisgibault L (2015) COP21 objectives: towards a joint energy transition in the Mediterranean? In COP21. Paris, pp 8

Brown MA (2001) Market failures and barriers as a basis for clean energy policies. Energy Policy 29(14):1197–1207

Cahill C, Legg W (1990) Estimation of agricultural assistance using producer and consumer subsidy equivalents: theory and practice. OECD Econ Stud 13:13–42

Château J, Dellink R, Lanzi E (2014) An overview of the OECD ENV-Linkages model. Organisation for Economic Co-operation and Development, Paris, OECD Environment Working Papers

De Broeck M, Kpodar R (2014) Mali: Automatic fuel pricing mechanism. International Monetary Fund, Washington, DC, Technical Assistance Report 14/31

Dhakouani A (2018) Multi-dimensional integrated modelling of the power system: towards renewable energy integration. UNIVERSITE DE TUNIS EL MANAR, Tunis

Dhakouani A, Gardumi F, Znouda E, Bouden C, Howells M (2017) Long-term optimisation model of the Tunisian power system. Energy 141:550–562

Dipa DD, Abedin K, Khan MM, Hasan MM (2015) Impacts of energy subsidy in Bangladesh: an analysis. ABC J Adv Res 4(1):39–56

Fattouh B, El-Katiri L (2012) Energy subsidies in the Arab world

Fattouh B, El-Katiri L (2013) Energy subsidies in the Middle East and North Africa. Energy Strateg Rev 2(1):108–115

Fisher AC, Rothkopf MH (1989) Market failure and energy policy A rationale for selective conservation. Energy Policy 17(4):397–406

Gardumi F (2016) A multi-dimensional approach to the modelling of power plant flexibility. Italy
Gargiulo M, Gallachóir BÓ (2013) Long-term energy models: principles, characteristics, focus, and limitations. Wiley Interdiscip Rev Energy Environ 2(2):158–177
Haas R, Panzer C, Resch G, Ragwitz M, Reece G, Held A (2011) A historical review of promotion strategies for electricity from renewable energy sources in EU countries. Renew Sust Energ Rev 15(2):1003–1034
Hanieh A (2015) Shifting priorities or business as usual? Continuity and change in the post-2011 IMF and World Bank engagement with Tunisia, Morocco and Egypt. Br J Middle East Stud 42(1):119–134
Hoffman KC, Jorgenson DW (1977) Economic and technological models for evaluation of energy policy. Bell J Econ 8(2):444–466
Hoffman KC, Wood DO (1976) Energy system modeling and forecasting. Annu Rev Energy 1(1):423–453
Howells M et al (2011) OSeMOSYS: the open source energy modeling system: an introduction to its ethos, structure and development. Energy Policy 39(10):5850–5870
IEA, World Bank, OPEC, and OECD (2010) Analysis of the scope of energy subsidies and suggestions for the G-20 initiative. G-20 Summit Meet Tor Can 5:81
IMF (2013) Energy subsidy reform: lessons and implications. *IMF eLIBRARY*. [Online]. Available: http://www.elibrary.imf.org/page/120. Accessed: 01 July 2017
Kaltenbacher B, Neubauer A, Scherzer O (2008) Iterative regularization methods for nonlinear ill-posed problems, vol 6. Walter de Gruyter, Berlin
Kern F, Smith A (2008) Restructuring energy systems for sustainability? Energy transition policy in the Netherlands. Energy Policy 36(11):4093–4103
Kleinbard ED (2010) The congress within the congress: how tax expenditures distort our budget and our political processes. Ohio North Univ Law Rev 36:1
Koplow D (2009) Measuring energy subsidies using the price-gap approach: what does it leave out? Social Science Research Network, Rochester, NY, SSRN Scholarly Paper ID 1631668
Lin B, Jiang Z (2011) Estimates of energy subsidies in China and impact of energy subsidy reform. Energy Econ 33(2):273–283
Madlener R, Bernstein R, González MÁA (2011) Econometric estimation of energy demand elasticities, vol 3. E. ON ERC, Aachen
Mead WJ (1979) The performance of government in energy regulations. Am Econ Rev 69(2):352–356
Menanteau P, Finon D, Lamy M-L (2003) Prices versus quantities: choosing policies for promoting the development of renewable energy. Energy Policy 31(8):799–812
Mills E (2003) Risk transfer via energy-savings insurance. Energy Policy 31(3):273–281
Momani MA (2013) Factors affecting electricity demand in Jordan. EPE 5(1):1–9
Narula K, Nagai Y, Pachauri S (2012) The role of decentralized distributed generation in achieving universal rural electrification in South Asia by 2030. Energy Policy 47:345–357
OECD (2013) Analysing energy subsidies in the countries of Eastern Europe, Caucasus and Central Asia. OECD
Ogarenko I, Hubacek K (2013) Eliminating indirect energy subsidies in Ukraine: estimation of environmental and socioeconomic effects using input–output modeling. J Econ Struct 2(1):7
Olejarnik P (2013) World energy outlook 2013. International Energy Agency, Paris
Painuly JP (2001) Barriers to renewable energy penetration; a framework for analysis. Renew Energy 24(1):73–89
Plunkett H, Wilson R, Argy S (1992) The measurement of effective rates of assistance in Australia-Industry
Ryan D, Plourde A (2009) Empirical modelling of energy demand. In: International handbook on the economics of energy. Edward Elgar Publishing, Cheltenham
Saidur R, Islam MR, Rahim NA, Solangi KH (2010) A review on global wind energy policy. Renew Sust Energ Rev 14(7):1744–1762
Sdralevich MCA, Sab MR, Zouhar MY, Albertin G (2014) Subsidy reform in the Middle East and North Africa: recent progress and challenges ahead. International Monetary Fund, Washington, DC

Sovacool BK (2017) Reviewing, reforming, and rethinking global energy subsidies: towards a political economy research agenda. Ecol Econ 135:150–163

Société Tunisienne de l'Electricité et du Gaz (2017) Rapport d'Activité. STEG, Tunis, https://www.steg.com.tn/fr/institutionnel/publication/rapport_act2017/Rapport_Activite_steg_2017_fr.pdf.

Steenblik R (2003) Subsidy measurement and classification: developing a common framework. Environmental Harmful Subsid Policy Issues Chall OECD Paris. pp. 101–142

Toke D (2007) Renewable financial support systems and cost-effectiveness. J Clean Prod 15(3):280–287

Tunisian Parliament (2015) Production d'électricité à partir des énergies renouvelables, vol 38, pp 926–932

Tunisian Parliament (2016) les conditions et les modalités de réalisation des projets de production et de vente d'électricité à partir des énergies renouvelables, vol 71, pp 2764–2774

Tunisian Parliament (2017) Model validation for the transfer of electricity produced from renewable energy contract, vol 13, p 546

UNEP-DTIE (2008) Reforming energy subsidies: opportunities to contribute to the climate change agenda. UNEP

United Nations Environment Programme and International Energy Agency (2002) Reforming energy subsidy. Oxford

Urban F, Benders RMJ, Moll HC (2007) Modelling energy systems for developing countries. Energy Policy 35(6):3473–3482

USAID SARI (2004) Subsidizing rural electrification in South Asia: an introductory guide. Energy Program

Von Moltke A, McKee C, Morgan T (2004) Energy subsidies: Lessons learned in assessing their impact and designing policy reforms, vol. 15. Emerald Group Publishing Limited

Welsch M et al (2015) Supporting security and adequacy in future energy systems: the need to enhance long-term energy system models to better treat issues related to variability. Int J Energy Res 39(3):377–396

Zaman M, Shaheen F, Haider A, Qamar S (2015) Examining relationship between electricity consumption and its major determinants in Pakistan. Int J Energy Econ Policy 5(4):998–1009