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Role of fiscal instruments in promoting low-carbon technology innovation

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Role of Fiscal Instruments in Promoting Low-carbon Technology Innovation

A scoping study

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List of Abbreviations

AD : Accelerated Depreciation
ADEME : The French Environment and Energy Management Agency
AET : Average Electricity Tariff
AP : Appropriability
AR : Assessment Report
AUS : Australian Dollar
BRICS : Brazil, Russia, India, China and South Africa
CanREA : Canadian Renewable Energy Alliance
CB : Competitive Bidding
CCS : Carbon Capture and Storage
CDM : Clean Development Mechanism
CFPI : Complementary Fiscal Policy Instruments
CO_2 : Carbon Dioxide
CSP : Concentrating Solar Power
DBCCA : Deutsche Bank Climate Change Advisors
DCR : Domestic Content Requirement
DKK : Danish Krone
EC : European Commission
EE : Energy Efficiency
EEA : European Economic Area
EEG : Erneuerbare-Energien-Gesetz (Renewable Energy Sources Act)
EPIA : European Photovoltaic Industry Association
EU : European Union
EV : Electric Vehicles
FCV : Fuel Cell Vehicle

FECs : Firm Energy Certificates

FITP : Feed- in- Tariffs Premium

FITs : Feed- in- Tariffs

FYPs : Five Year Plans

GBI : Generation based incentive

GBI : Generation-Based Incentives

GE : General Electric

GGKP : Green Growth Knowledge Platform

GHG : Green House Gas

GW : Giga Watt

GWh : Gigawatt Hour

IEA : International Energy Agency

IGCC : Integrated Gasification Combined Cycle

IPCC : Intergovernmental Panel on Climate Change

IRENA : International Renewable Energy Agency

JNNSM : Jawaharlal Nehru National Solar Mission

KWh : Kilowatt-Hour

LBD : Learning-by-Doing

MNRE : Ministry of New and Renewable Energy

MOE : Merit Order Effect

MW : Mega Watt

NAPCC : National Action Plan on Climate Change

NCEF : National Low-Carbon Technology Fund

NDRC : National Development and Reform Commission

NREAP : National RE Action Plan

OECD : Organisation for Economic Co-operation and Development

P : Price based

PAT : Performance, Achieve and Trade

PFMs	: Public Finance Mechanisms
PHEV	: Plug in Hybrid Electric Vehicles
PII	: Policy Impact Indicator
PPM	: Parts per Million
PPPs	: Public Private Partnerships
PROINFA	: Programme of Incentives for Alternative Electricity Sources
PTC	: Production Tax Credit
PV	: Photovoltaic
Q	: Quantity based
R&D	: Research and Development
RAM	: Reverse Auction Mechanism
RD&D	: Research, Development and Deployment
RE	: Renewable Energy
RE	: Renewable Energy
REC	: Renewable Energy Certificate
RES	: Renewable Energy Systems
RES-e	: Renewable Energy Sources
RES-H	: Renewable Energy Sources of Heat
RET	: Renewable Energy Technology
RPO	: Renewable Purchase Obligation
RPSs	: Renewable Portfolio Standards
RRF	: Renewable Regulatory Fund
STI	: Science, Technology and Innovation
T&D	: Transmission and Distribution
TCI	: Total Cost Indicator
TGCs	: Tradable Green Certificates
TGFs	: Tradable Green Certificates
TLC	: Transparency, Longevity and Certainty

UK : United Kingdom

UNEP : United Nations Environment Programme

USA : United States of America

USCSC : The US Carbon Sequestration Council

USD : United States Dollar

VGF : Viability Gap Funding

WE : Wind Energy

WEO : World Energy Outlook

WG : Working Group

WHO : World Health Organization

WITCH : World Induced Technical Change Hybrid model

WRI : World Resources Institute

WWF : World Wildlife Fund

Role of Fiscal Instruments in Promoting Low-carbon technology Innovation

A scoping study

1. Introduction

1.1 Importance of promoting low-carbon energy technologies

Achieving the steep climate change mitigation targets the world is faced with would require both deployment of known 'low-carbon' energy technologies and invention of new technologies[1]. The magnitude and pace of technological transformation required in this context is highly challenging and unprecedented[2]. At least two challenges differentiate this with other cycles of technological transformations, in general as well as in the energy sector, than those encountered in the past—the need for systematically internalizing the externalities (social and environmental costs) and the huge upfront investment in technologies and supporting infrastructure (e.g. power lines to connect renewable plants, pipelines for CCS) without having markets that signal the real scarcities; and the global scale of the challenge and the fast pace of much needed innovation (Altenburg et al, 2014; Goulder and Parry, 2008; Narayanamurti et al., 2011).

The other potential opportunities that low-carbon energy technologies present include: energy security, development dividends through poverty reduction, health benefits[3], opportunities for economic growth and employment generation[4], and gains from trade in an ever growing international market for energy. Gainful exploitation of low-carbon energy opportunities would on the one hand depend on policies, capacities, local circumstances and the drive of individual countries, and on the other, would imply technological innovation (covering existing, emerging, and breakthrough technologies) that has not been seen before and thus demanding that the research, development, and deployment (RD&D) in low-carbon energy be put on center stage. However, progress so far has been less than desirable. For instance, the International Energy Agency (IEA) estimates a shortfall between the current $10 billion in annual public RD&D spending and the $40 to $90 billion of investment needed for low-carbon energy technologies (Table 1).

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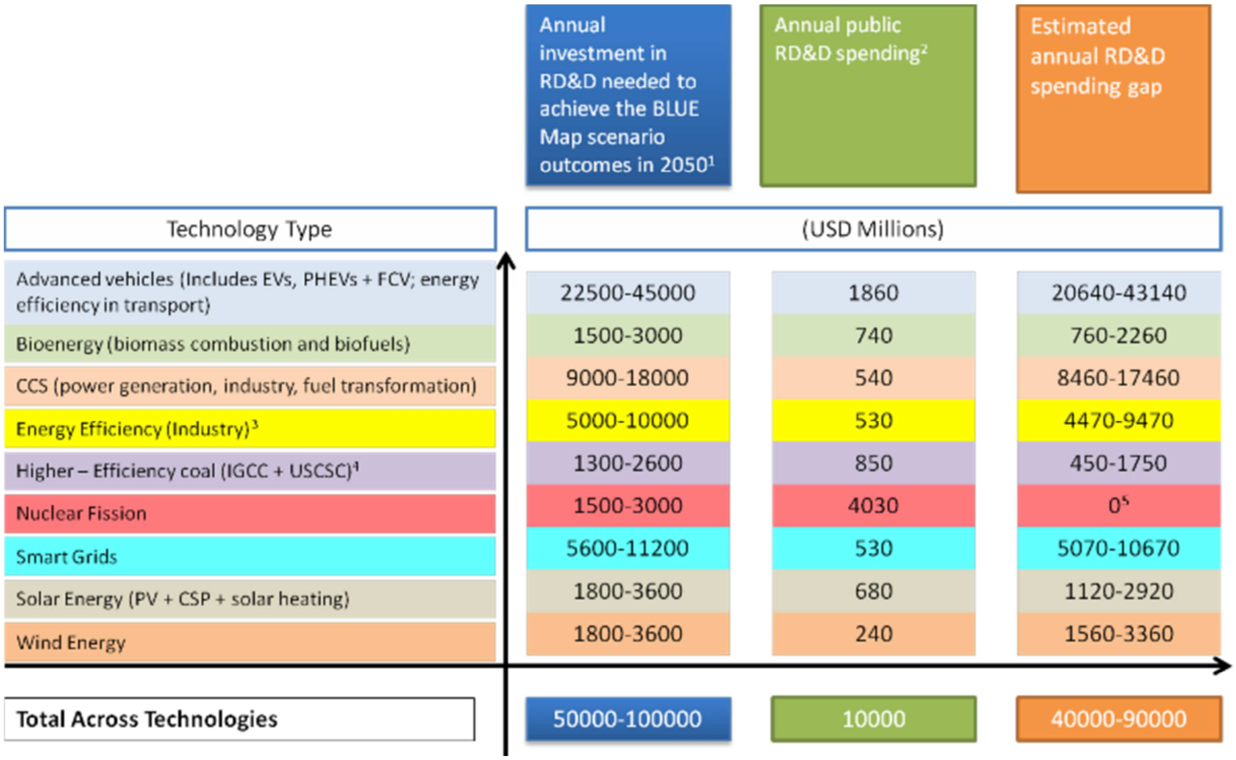
[1] The IEA's Energy Technology Perspectives 2010 highlights the urgent need to deploy a wide range of low-carbon technologies in order to achieve the goal of halving greenhouse-gas emissions by 2050 while also promoting energy security (IEA, 2011).

[2] About two thirds of man-made greenhouse gas emissions result from burning of fossil fuels (IPCC AR5). Hence, we need a "fundamental transformation of the energy sector", including a "long-term phase-out of unabated fossil fuel conversion technologies" (IPCC AR5, WGIII. Technical Summary, Page 46).

[3] WHO reports that in 2012 around 7 million people died - one in eight of total global deaths – as a result of air pollution exposure. Regionally, low- and middle-income countries in the WHO South-East Asia and Western Pacific Regions had the largest air pollution-related burden in 2012, with a total of 3.3 million deaths linked to indoor air pollution and 2.6 million deaths related to outdoor air pollution.

[4] However, it is important to note that some growth and employment gains will be offset by contraction in certain industries (e.g., coal).

Table 1: Estimated annual RD&D spending gap to achieve the BLUE Map scenario outcomes



Technology Type	Annual investment in RD&D needed to achieve the BLUE Map scenario outcomes in 2050[1]	Annual public RD&D spending[2]	Estimated annual RD&D spending gap
	(USD Millions)		
Advanced vehicles (Includes EVs, PHEVs + FCV; energy efficiency in transport)	22500-45000	1860	20640-43140
Bioenergy (biomass combustion and biofuels)	1500-3000	740	760-2260
CCS (power generation, industry, fuel transformation)	9000-18000	540	8460-17460
Energy Efficiency (Industry)[3]	5000-10000	530	4470-9470
Higher – Efficiency coal (IGCC + USCSC)[4]	1300-2600	850	450-1750
Nuclear Fission	1500-3000	4030	0[5]
Smart Grids	5600-11200	530	5070-10670
Solar Energy (PV + CSP + solar heating)	1800-3600	680	1120-2920
Wind Energy	1800-3600	240	1560-3360
Total Across Technologies	50000-100000	10000	40000-90000

Source: IEA (2010)

Notes:

1. RD&D investment needs derived using 10% to 20% of average deployment costs for BLUE Map scenario (the BLUE Map scenario (with several variants) is target-oriented: it sets the goal of halving global energy-related CO2emissions by 2050,compared to 2005 levels, and examines the least-cost means of achieving that goal through the deployment of existing and new low-carbon technologies; see IEA 2010) and adjusted by a factor of 90% to reflect country coverage
2. IEA 2007 data with the following exceptions: Australia (2009-2010 estimated); Canada (2009 estimated); France (2007 revised via direct submission); Germany (2009 estimated); USA (2009 estimated). The non-member country data were taken from IEA (2009e). When necessary, spending calculated using 2008 exchange rates
3. Estimates for building energy efficiency RD&D needs were not available
4. Integrated gasification combined cycle and ultra-supercritical steam cycle
5. The gap for nuclear fission is assumed to be zero excluding any additional RD&D for Gen IV technologies. Therefore the sum of the estimates for the gap by technology do not sum to the total.

The emissions control policies (e.g. market-based – getting prices right — approach (emission pricing, emission trading, environmental fiscal reform) have been argued as an efficient solution[5] to achieving GHG emission reduction targets. For, these could potentially work as an incentive to technological innovation in low-carbon energy and also to changes in consumer behavior. However, theoretical and empirical literature suggests that government intervention in the innovation process through additional policies to promote low-carbon energy technology is necessary because environmental externalities are not the only market failure inherent to low-carbon energy technologies (Box 1).

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[5] The economic efficiency argument favoring this approach is that it does not necessarily distinguish between the potential solutions—e.g. renewable energy, energy efficiency, CCS etc.

Box: 1

The energy sector is also affected by market failures associated with technology innovation and diffusion (knowledge externalities, and adoption externalities) ─ which has implications for both efficiency and how much cleaner the energy mix and the systems and machines/devices run on energy can become (Jaffe et al. 2005).The difficulty industry faces in fully appropriating the benefits of R&D (and preventing competitors from capturing some of the benefits) has been thoroughly explored in the economics and business literature, and represents one of the main justifications for government support of R&D (See Section 2.2.2).

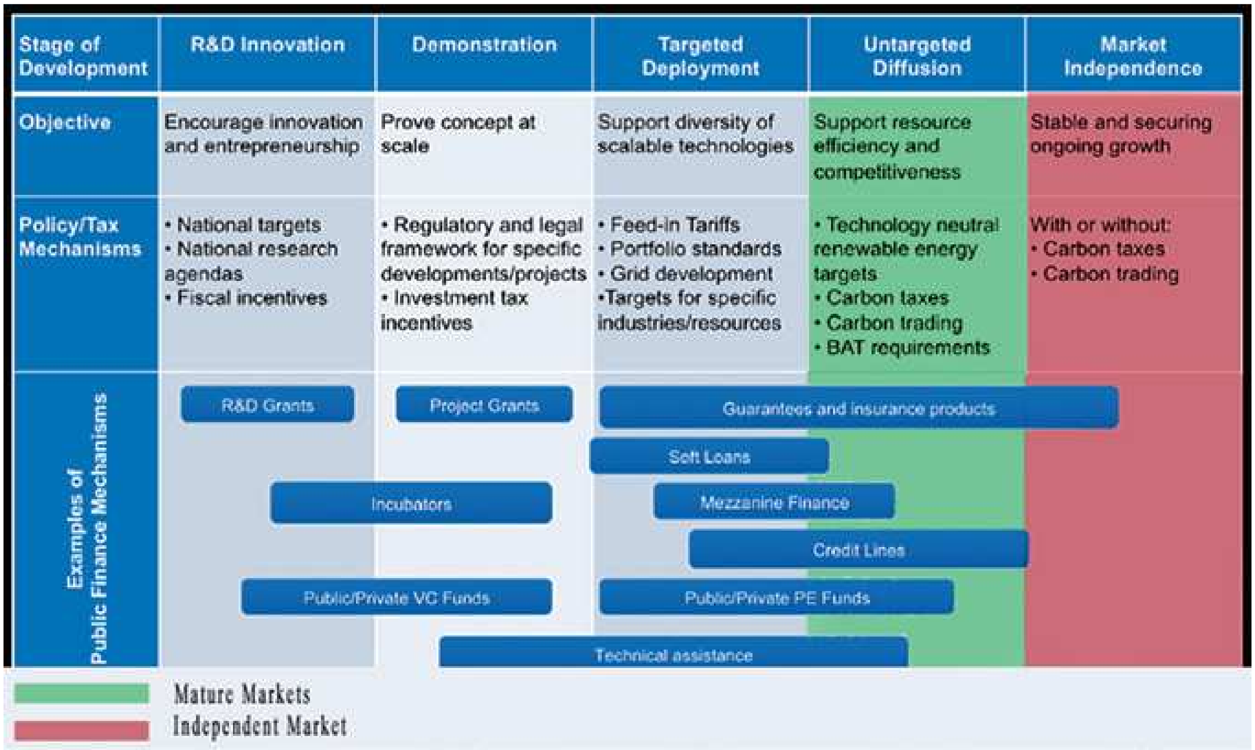
Also, since emissions control policies provide innovation incentives only indirectly (by emissions pricing or by raising the costs of conventional production methods through direct regulation) these may be insufficient to foster the necessary investment in research and development of new low-carbon energy technologies (Cohen and Noll, 1991);as well as to stimulate the dynamic learning process in known technologies to bring down the costs to an economically competitive level (Griliches 1992; Mansfield 1985; Levin et al. 1988; and Jones and Williams 1998).

Many of the most promising low-carbon technologies currently have higher costs than the fossil-fuel based technologies. It is only through learning from RD&D that these costs can be reduced (IEA, 2010). Government intervention in the innovation process can be useful to accelerate this process beyond what would be expected from market forces alone, and catalyze early adoption.

For a number of other barriers which impact the competitiveness of low-carbon energy and thus their penetration in the market (See Section 2.2.2).

As a consequence, countries across the world have implemented a wide range of public policy instruments to promote research, development, and deployment (RD&D) of low-carbon energy technologies (Azuella and Luiz, 2011). A snap shot of these instruments by stages of innovation is in Figure1. This, however, has been achieved with varying levels of success and direct and indirect costs (Gillingham and Sweeney, 2012). Public policy instruments by nature put pressure on governments' budgets and thus, in turn, have implications for their ability to maintaining funding support to investment flows in low-carbon energy sector (UNEP, 2011). This is a serious concern and requires that public policy instruments to foster the necessary investment in RD&D of low-carbon energy technologies are efficiently designed and implemented.

Figure 1: The Low-Carbon Technology Continuum



Stage of Development	R&D Innovation	Demonstration	Targeted Deployment	Untargeted Diffusion	Market Independence
Objective	Encourage innovation and entrepreneurship	Prove concept at scale	Support diversity of scalable technologies	Support resource efficiency and competitiveness	Stable and securing ongoing growth
Policy/Tax Mechanisms	• National targets • National research agendas • Fiscal incentives	• Regulatory and legal framework for specific developments/projects • Investment tax incentives	• Feed-in Tariffs • Portfolio standards • Grid development •Targets for specific industries/resources	• Technology neutral renewable energy targets • Carbon taxes • Carbon trading • BAT requirements	With or without: • Carbon taxes • Carbon trading

🟩 Mature Markets
🟥 Independent Market

Source: Ibaris and Climate Bonds Initiative (2011); UNEP (2011)

1.2 The scoping study (objective, focus, approach)

Against this background, the Fiscal Instruments Research Committee commissioned a scoping study on 'The Role of Complementary Fiscal Instruments in Promoting Low-Carbon Energy Technology Innovation' focusing on appropriate choice and design of instruments to address specific barriers, drawing on lessons learnt from experiences with complementary fiscal policy instruments (CFPI) in developed and developing countries (e.g. how to identify and design a policy to ease specific barriers for a given technology and other background variables; and how to identify a slowing down and an exit strategy). This study focuses on CFPI primarily for renewable energy (RE), although the study also discusses some experiences in implementation of CFPI for energy efficiency (EE) in the passing.

The study is based on literature review and email interactions with the research committee and feedback from the participants at the GGKP Annual Conference in January 2015. Review of case studies to gain insights on specific points (instrument choice, design and experience/outcome) in the narrative is an important component of the study; accordingly main insights from the case studies will be included into the study through case boxes at appropriate places.

1.3 Organization of the report

The remainder of the report is organized as follows: Section 2 outlines some guiding principles underlying the choice and design of complementary fiscal policy instruments, discusses different criteria in evaluating the efficiency of such incentives in particular the question of stimulating technical change, and emphasizes the need to identify the drivers and barriers in appropriate choice and design of complementary fiscal policy instruments. Section 3 contains a discussion on taxonomy of RE enabling direct and indirect instruments and policies. Section 4 critically reviews the different policy instruments deployed as support to RE technologies and provides useful insights on the lessons learnt from these programs for future policy design and implementation. Section 5 provides discussion on issues in how to allow built-in flexibility level and timing of slowing/tapering and an exit point/policy. Section 6 presents some country case studies and Section 7 concludes.

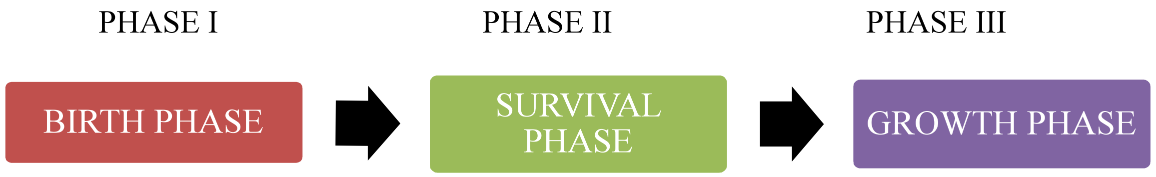
2. Choice and Design of Complimentary Technology Instruments: Setting the Stage

A number of domestic and international considerations both inform as well as influence the choice and design of CFPI in a country. Thus identifying the appropriate instrument is a substantial challenge. The entire process from planning to development of CFPI can broadly be divided into two stages: (i) setting the stage (articulating an energy R&D framework and clearly identifying the barriers faced by different technologies); and (ii) basic guiding principles in actual design and implementation stage. Although the focus of this study is on the latter, some discussion on the former is necessary in order to put things in perspective and set the context.

2.1 Setting the stage: Need for an energy RD&D policy framework

An innovative idea[6] translating itself into a successful technological development goes through the following phases (Pandey et al, 2014) see Figure 2 below:

Figure: 2 Different Phases of Innovation Continuum



In phase I, an idea gets converted into a workable prototype/process (R&D and demonstration stages). The next phase is called the 'Survival Phase' wherein up-scaling of the prototype to the pilot plant/pre- commercial stage is done (deployment and diffusion stages). In phase III the pilot production is up scaled to commercial production (commercial maturity stage).

In this context, the following three issues, at least, are important and directly concern with the choice and design of CFPIs (Box 2).

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[6] No distinction is made in this paper between innovation and invention. For a discussion on distinction between innovation and invention see Narula (2003). An invention may be an idea, model, or sketch of a device, product, or process; in contrast, an innovation occurs when a device, product, or process is involved in a commercial transaction. A particular innovation may be a product of several inventions, and so the ability to transfer invention to innovation is an important capability in itself (IRENA, 2013).

Box: 2

One, a particularly challenging question is how to identify which technologies need to be promoted which underscores the need for an energy RD&D policy framework.

Two, countries may aspire to promote all three phases/five stages simultaneously, or may focus on deployment wherein technology is sourced internationally, or may focus on I-III with emphasis on development of domestic manufacturing capacity. When faced with multiple drivers/objectives, an important issue to consider is how to integrate the policy instruments so as to reduce the tradeoffs and improve the synergies between multiple objectives.

Three, the characterization of technologies by phases/stages can help contextualize the types of innovation activities that are possible and/or necessary to advance a given technology at a given time, and thus help determine which types of policy instruments, and the level and duration of support might be appropriate for a technology at a specific stage of risk and maturity[7].

Appropriate energy RD&D policy frameworks[8] are one of the cornerstones of energy technology promotion. A coherent and co-ordinated RD&D energy strategy – with clear prioritization in line with national energy policy goals – is the most important feature of a good practice energy RD&D framework (Fulton, 2011) (Box 3). Such a strategy when based on a dynamic strategic vision (which is developed in close consultation with major stakeholders and is frequently updated) can improve the confidence and trust of potential investors in the reliability of targets and policy ambitions and thus boost the pace of RD&D of low-carbon energy technologies (IEA, 2011; Pandey et al, 2014; Kammen, et al, 2004). A review of energy RD&D priorities in select countries based on announced technology programmes/strategies is presented in Annexure A. *Such an exercise can not only help draw clear linkages of policy instruments with the targets but also help monitor the impact of policy instruments.*

In addition, a strong commitment from governments to make RD&D a sustainable and attractive proposition for all stakeholders will be important. This is achieved when clearly defined energy production goals and realistic targets -- and not *adhoc* programmatic or fiscal interventions-- guide the medium-term to long-term direction of the energy innovation portfolio (Pandey et al, 2014; Kammen et.al 2004; IEA, 2011; Fulton, 2011). Countries with small grid capacities, for example, may need to set targets which would reflect grid capacities and hence may initially promote distributed generation over centralized generation. In the case of both wind and PV technology, promotion of power storage technologies would dramatically enhance their effectiveness. According to Margolis and Kammen (1999); and Kammen et al (2004), many R&D programs with *adhoc* funding cycles, can at times do more harm than good to RD&D of specific technologies. For example, R&D programs in USA, for solar and fuel cell systems have not been focused on committed goals but instead to spend available funds which often had to be justified on unrealistically short timetables.

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[7] Feedbacks and linkages are often present between these different stages, and the boundaries between them are porous: for example, feedback from the market and from technology users during the commercialization and diffusion phases can lead to additional RD&D, driving continuous innovation (IEA, 2011).

[8] Which is seen as a constantly evolving process – defined by an approach to: creating change through continuous learning and adaptation; and supporting development and promotion of a variety of technologies as well as different organizational types of energy production (e.g. centralized vs. decentralized electricity generation).

Box: 3

An energy RD&D policy framework based on good practices

1. Coherent energy RD&D strategy and priorities
2. Adequate government RD&D funding and policy support
3. Co-ordinated energy RD&D governance
4. Strong collaborative approach, engaging industry through public private partnerships (PPPs)
5. Effective RD&D monitoring and evaluation
6. Strategic international collaboration

Source: IEA, 2011

Germany's integrated climate and energy policy, and RE Technologies planning

- Germany has set a target of 30% RE by 2020 and 50% by 2030.
- The National RE Action Plan (NREAP) projected that it would achieve 38.6% RE by 20202 (projection of how the market might grow).
- To meet national targets and NREAP trajectories, Germany projects that the two fastest growing RE technologies will be wind and PV during 2010-2020.
- Wind will therefore contribute 48% of total RE in 2020 and PV will account for 19%.
- Projections are made for both total installed capacity as well as annual additions. These details enable the government to design strategies for volume management.

Source: Based on Fulton, 2011

2.2 Setting the stage: Identification of drivers and assessment of barriers

The nature and magnitude of drivers of and barriers in development and adoption of low-carbon energy technologies both guide the direction of the low-carbon energy technology policy as well as determine the choice and design of public policy instruments in promoting RD&D of low-carbon energy technologies in a country. To set the context, we briefly discuss the common drivers and barriers in investment in low-carbon energy, although the significance of one driver/barrier over the other may vary across the countries, technologies, and stages of RD&D etc.

2.2.1 Drivers of promoting low-carbon energy technologies

Six drivers/energy development goals that, either alone or in combination, commonly shape energy development pathways, are identified (IRENA, 2013) as follows:

- Green House Gas (GHG) emissions reduction;
- Energy Security;
- Energy Access;
- Energy Cost;
- International Competitiveness; and
- Modernization

Broadly, these are in harmony with the opportunities in development of low-carbon technologies listed in Section 1.1 (e.g. poverty reduction goals in developing countries will correspond with energy access and employment; and trade gains will accord with energy cost and international competitiveness goals). The choice of one or more of these goals and their relative weights will depend on various countries specific factors (e.g. demand/supply of energy, technical capacity, market structure, and existing institutions and regulations). *Together these will guide the direction of the low-carbon energy technology policy as well as the choice of public policy instruments in promoting RD&D of low-carbon energy technologies.* This however, is a step-by-step process. An analytical framework which identifies: (i) general characteristics of each driver/goal, (ii) various steps/functions involved in promoting innovation in the context of each driver/goal, and (iii) examples of policy tools that will help accelerate the process and enhance the outcomes is presented in Table 2. While the processes (and end results) will look significantly different across various national contexts, the framework is expected to be relevant to policy-makers in many settings.

Table 2: Characteristics of drivers, functional steps and examples of policy tools

Drivers	**Functions**						
	Creating and Sharing New Knowledge	***Building Competence and Human Capital***	***Knowledge Diffusion / Creating Collaborative Networks***	***Developing Infrastructure***	***Providing Finance***	***Establishing Governance and the Regulatory Environment***	***Creating Markets***
	Policy Tools						
Energy Security (reducing dependence on vulnerable energy supplies)	Support studies to quantify value of energy security; High-resolution RET resource assessments; Grid modeling to estimate performance under varying penetrations of RETs.	Subsidies and incentives for education and training in power sector engineering, Project development, finance, engineering and construction.	Joining international cooperation seeking energy security; To identify gaps and prospects regarding energy use and efficiency.	Facilitating huge RET deployment via investment in grid infrastructure, roads, rail, and ports.	Project finance loan guarantees; "Green" banks or revolving funds; Public bonding support for infrastructure	Intellectual property protection and legal recourse for joint ventures; To improve investment climate; Specific and credible energy efficiency and renewable energy targets; Utility-scale interconnection standards.	Feed-in tariffs; Renewable Portfolio Standards; Government/public procurement.
	Policy Tools						
Energy access (reducing energy poverty and expanding access to secure, reliable, and low-cost energy)	High-resolution RET resource assessments in low energy access areas; Studies to quantify market size of low- and middle-income consumers; Opportunity and gap analysis of RET deployment in off-grid settings; Analysis of future grid modernization pathways.	Subsidies and incentives for education and training in off-grid system design and equipment maintenance, micro-grid design and engineering, power system planning; entrepreneurship, marketing, micro-finance.	Joining international cooperation for expanding energy access; Supporting community groups and entrepreneurs for RET deployment; Supporting micro-finance networks.	Enabling grid development in high-priority areas; Improving telecommunications coverage for novel smart grid applications.	Support energy technology micro-finance models; Removing barriers to Traditional and novel finance pathways.	Setting specific energy access targets; Establishing micro-grid interconnection standards, Bolstering property rights for low-income citizens; Removing barriers to new business models, e.g. solar system leasing.	Feed-in tariffs extending to micro-grid operators and low-income citizens; Public Procurement of RET systems in government-subsidized housing.
	Policy Tools						
Cost (reducing exposure to persistently costly energy services)	High-resolution RET resource assessments; Energy road-mapping and System analyses; Grid capacity studies.	Subsidies and incentives for education and training in off-grid system design and RET equipment maintenance, micro-grid design	Initiating international cooperation; Supporting community groups for energy access and towards micro-finance networks.	Grid modernization; Vehicle electrification infrastructure; Biomass logistics and processing infrastructure.	Project finance loan guarantees; Alliance with international bodies to support financing and insurance of RET systems; Support for energy technology micro-	Establishing distributed generation and micro-grid interconnection standards; Designating RET project development areas; Setting energy efficiency standards;	Renewable Portfolio Standards; Feed-in tariffs; Energy Efficiency Obligations; Public procurement of RET systems in government buildings; Incentives for alternative fuel vehicles and energy

		and engineering, power system planning; Biofuels production, energy efficiency, entrepreneurship, marketing, micro-finance.			finance models; Removing barriers to novel finance pathways.	Removing barriers to novel business models, such as energy performance contracting or solar system leasing.	efficiency.
	Policy Tools							
Competiveness (Trade; achieving greater competitiveness in international energy markets)	Detailed international market and supply chain studies; Detailed analysis of domestic industrial and service capabilities.	Subsidies and incentives for education and training in international business, foreign languages.	Brokering international joint ventures; International conferences to showcase indigenous capabilities; Supporting trade missions to markets; Participation in multilateral trade bodies.	Less critical in this policy setting.	Credit guarantees to improve creditworthiness of domestic firms in joint ventures.	Intellectual property protection and legal infrastructure to support joint ventures or international collaboration.	Less critical in this policy setting.
	Policy Tools							
Modernization (modernizing national energy systems)	High-resolution RET resource assessments; Energy road-mapping and associated System analyses; Grid capacity and expansion studies.	Subsidies and incentives for education and training in power sector engineering, renewable resource assessment, project development and system engineering, finance, and international business.	Hosting conferences to showcase investment opportunities; Brokering International joint ventures; Supporting reverse trade missions to firms.	Transmission expansion tailored to RE resources; Enhancements to shipping and Logistics infrastructure.	"Green" banks or other credit facilities; Project finance loan guarantees; Credit guarantees or other instruments to improve creditworthiness of domestic firms in joint ventures.	Grid interconnection standards; Establishment of priority transmission zones; Enhancements to intellectual property protections and determinants of investment climate.	Feed-in tariffs; Renewable Portfolio Standards; Government/public procurement.
	Policy Tools							
GHG emissions reduction, focusing on reducing the GHG and impacts on environment	Subsidies for basic research, stimulate international technology and knowledge flows.	Subsidies and incentives for education and training in power sector engineering, project development, finance, engineering, and construction.	Joining international cooperation seeking GHG emission reduction; to identify gaps and prospects regarding energy use and efficiency.	Facilitating RET deployment via investment in grid infrastructure, roads, rail, and ports.	Project finance loan guarantees; "Green" banks or revolving funds; Public bonding support for infrastructure	Intellectual property protection and legal recourse for joint ventures; To improve investment climate; Specific and credible energy efficiency and renewable energy targets; Utility-scale interconnection standards.	Feed-in tariffs; Renewable Portfolio Standards; Government/public procurement, carbon pricing, reforming subsidies to fossil fuel based energy.

Source: Based on IRENA, 2013

2.2.2 Barriers in development and adoption of low-carbon energy technologies

A clear understanding of the barriers faced by different low carbon technologies is required to develop the relevant and effective policies. Most common barriers are listed in Box 4.

Box 4

- Inadequate pricing of environmental externalities (lack of/ imperfect emissions policy);
- Un-priced benefits of innovation (knowledge externalities, adoption externalities)[9];
- Policy barriers (such as fossil fuel subsidies) which artificially reduce the competitiveness of low-carbon technologies (in most countries, subsidies to support the production and consumption of fossil fuel-based energy are more than the subsidies to low-carbon energy); and
- Market failures due to imperfect information.

Besides, fossil fuel based technologies have several other advantages, which work as barriers for low-carbon energy, such as:

- Well-organized energy markets and delivery systems for conventional energy;
- Availability of supporting infrastructure;
- Consumers' familiarity with costs, risks and performance;
- Financial sector understands the risks and market demand etc. relatively better.
- Institutional barriers (gaps in institutional capacity to support adoption of new technologies and to monitor and enforce performance standards).

Source: Authors

Besides, some key characteristics of technologies and projects that may be relevant in identifying market barriers are:

- *Relative Maturity*: The commercial maturity of technology reduces the risk to investor and is capable of overcoming market barriers. The regional specificity of the technological issues will still be valid in certain cases, for example, integrated gasification combine cycle would require demonstration and validation in developing countries owing to the issues varying qualities and composition of the coal feedstock.
- *Base-load versus variable*: The intermittent output from many renewable energy systems is a critical performance weakness and remains a hindrance to their substitution for base-load thermal generation. The technologies such demand side management, energy efficiency, and energy storage technologies may address the challenges associated with such systems.
- *Incremental versus breakthrough*: Incremental versus breakthrough connote difference in the degree of change from the current technology, with breakthrough implying a step change. Steady improvement in the operating efficiency of equipment and appliance is typically achieved through incremental change. Technologies are often categorized as being breakthrough after they become economic and deployed on a commercial scale.
- *Policy dependence*: Investment in many energy technologies is highly dependent on regulatory decision to allow, mandate, or facilitate their use with financial support. The financial attractiveness of wind turbines, solar, power and other forms of distributed power

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[9] Although market failures are not limited to the clean energy sector, the case for public policy support for clean energy technologies in the context of climate change mitigation is magnified due to the need for quick and decisive actions owing to the threat of climate change, and lingering uncertainties about how climate change policies will play out in terms of their impacts on relative price of low-carbon energy and thus enthusiasm for innovation in low-carbon energy (Fischer and Newell 2007; Montgomery and Smith 2007).

generation requires favorable polices for access to utility grids and, very often, direct government subsidization.

The significance of one barrier over the other may vary across countries, technologies, and the stage of RD&D etc. Given this, there is a case for government support as a way of correcting these barriers.

While the standard characterization of market failures is the inability of the markets to fully internalize the social costs/benefits in pricing mechanisms, the market barriers are disincentives adversely impacting market entry and/or adoption/use of solutions/devices/products and services (Groba and Breitschopf, 2013). Further, while market failures as the term suggests, are necessarily linked to the poor functioning/absence of markets, the market barriers could be linked to the functioning of the markets, regulatory and fiscal policies, social and cultural factors, and asymmetric information etc. Selected market failures and barriers are listed in Table 3.

Table 3: Selected market failures and barriers to RE innovation, adoption and diffusion

Market failures	
Un-priced costs and negative externalities • Un-priced social costs of emissions • Un-priced social costs of supply vulnerability, price and national security risks	**Economies of scale and market power** • Un-priced benefits of learning-by-doing • marginalization of new technologies due to market power exerted by conventional energy companies
Un-priced benefits and positive externalities • Un-priced benefits of innovation/knowledge	**Information market failures and distortions** • high transactions cost of information • principal-agent problems • policy coordination problems
Market barriers	
Low priority and awareness of energy issues Capital market barriers • uncertainty of future energy prices • high discount rates • capital-intensive investments in RET	**Distortionary fiscal and regulatory policies** • subsidies for conventional energy sources • administrative project approval procedures • unfavorable standards for RE

Source: Groba and Breitschopf (2013)

- The most documented market failure in the case of most technologies is the difficulty in protecting research, especially basic research. This may also be interpreted as the inability in fully capturing the benefits of R&D. In particular, other firms might copy, legally imitate, or use the knowledge about the new technology to advance their own research (Goulder and Parry 2008). Empirical studies suggest that the (marginal) social return to innovation in general might be greater than the (marginal) private return (Griliches 1992; Mansfield 1985; Levin et al. 1988; and Jones and Williams 1998). In addition, research may unintentionally produce results that the innovator cannot use effectively. Not being able to reap full gains from investment may mean disincentive to the innovator/investor resulting in less than optimal investment in low-carbon technology R&D, thus justifying governmental intervention in the form of public sector research, subsidies for private R&D, tax credits, stricter patent rules, etc. While appropriability (AP) issue may arise in all three phases of the innovation, R&D spillovers may be much more important for very early stage R&D, rather than technologies at the pilot or implementation stage Nordhaus (2010).

- Another market failure may arise from knowledge spillovers post pilot stage of innovation. It is usually argued that learning-by-doing (LBD)[10] is necessary in bringing down the costs of technologies. This is supported by empirical evidence (Ek and Söderholm, 2010; IEA, 2010; Isoard and Soria, 2001; Junginger et al., 2010; Kahouli-Brahmi, 2009; Klaassen et al., 2005; Neij, 2008; Söderholm and Klaassen, 2007) though actual size of learning rates may vary widely for specific technologies (Lindman and Söderholm, 2012). However, competitors may benefit by the external benefits of the efforts of early adopters. Consequently, investments in learning will be sub-optimal to stimulate the efficient levels of cost reduction. Just as in the R&D spillovers, the lack of full appropriability of the gains is a positive externality and thus forms the basis for the market failure in LBD. However, potential for deployment-related knowledge spillovers may vary greatly depending on the product involved. Empirical evidence on LBD is still limited (Lehman, 2013) relying primarily on anecdotal observations (Junginger et al, 2005). The only econometric analysis is provided by Braun et al. (2010). Based on patent data, they show that innovation in wind and solar technologies is strongly driven by knowledge spillovers.
- These AP and LBD market failures lead an innovator/investor to under-invest or under-produce, relative to economically efficient level; thus adversely affecting the pace of adoption.
- Innovation in low-carbon energy technologies often has very high capital requirements, and involve long time horizon. Like any R&D it involves substantial economic, technical and regulatory risks that hamper access to finance. Economies of scale[11] can be considered a barrier or market failure if there are capital constraints or a simultaneous coordination problem. Capital constraints issue is likely to be more significant in emerging economies which lack active angle investors, venture capitalists, and private equity institutions. In developed economies this may be viewed as a transient concern. However, quantifying LBD separately from the economies of scale and exogenous technologies change is a difficult empirical challenge for which there is only very limited evidence (e.g. Nemet 2006; Gillingham and Bollinger 2012). Simultaneous co-ordination problems are more likely to occur in developing a new infrastructure for electric or hydrogen vehicles (Gillingham and Sweeny 2010), provision of smart grid etc. Empirical evidence on the extent of the learning – by – doing spillovers as well as inability to appropriate full benefits of R&D is limited constraining the optimal policy design.
- Yet another potential market failure may arise from consumer myopia causing undervaluation of benefits of energy efficiency/low-carbon energy. In addition poor information and cultural and social barriers to do things differently present strong resistance to adoption.
- While identification of specific barriers that limit the progress in RE technology innovation and diffusion in general is required, it is necessary to differentiate the barriers by different RE technologies and different stages of innovation (Gillingham and Sweeney 2012). The tables below are an attempt in this direction (See Tables 4-5).

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[10] LBD implies that the unit cost of a product/service decreases with increasing cumulative investment, production, and market growth.

[11] Other barriers related to the technical and economic characteristics of RE stand in its way of diffusion besides its capital intensive profile include the need to mobilize mass production effects rather than scale effects because of their size limitations, and in certain cases their failure to generate energy on a continuous basis (Menanteau et al , 2003).

Table 4: Market failures and barriers in RE by technologies

Technology	**Market failure**	**Remarks**	**Barrier**	**Remarks**
Central generation	AP , LBD	The evidence on the extent of the R&D and LBD, AP remains very limited. Quantifying this is very difficult. Similarly, quantifying LBD separately from the economics of scale and exogenous technologies change is a difficult empirical challenge.	Capital constraints, simultaneous coordination problem	A simultaneous co-ordination problem has some similarities to a public goods problem, and may provide motivation for either government co-ordination of different agents or possibly government provision of the good or service.
Distributed RE	AP and LBD may be relevant		These technology may face the same barriers as in central generation	The only major difference is that in this case, consumers (and sometimes firms) are the purchasers of the technology, rather than electric utilities as in the case of centralized generation.
CCS Technologies	Theoretically same AP issues are likely to apply in the case of CCS	However, since much of the research in this area is being done by the Public Sector the AP would not apply.	The most fundamental barriers to CCS are high cost (early stage technology which is highly energy intensive).	Concerns of leak out of carbon, risk of abrupt release of CO2 and the consequent liability risk and public acceptance.

Source: Based on Gillingham and Sweeney, 2012.

Table 5: Market failures and barriers in RE by different stages in innovation

Phases of Innovation	**Market Failures**	**Barriers**	**Potential Policy Instruments**
Birth Phase (R&D) Basic research to fundamental breakthrough Conceptual breakthrough to lab scale model	Positive externality Inability to appropriate full benefits of R&D and knowledge spill-overs	Under investment in R&D relative to economically efficient level.	Subsidize R&D; Government investment in R&D; Soft loans; Tax credit
Survival Phase (Deployment) • Lab – to – pilot • Targeted deployment • Untargeted diffusion	Positive externality • This is learning by doing phase for cost reductions. Learning spillover is a strong possibility • Economies of scale	Under production relative to economically efficient level. The pace of deployment may be adversely affected. • Capital constraints and/or co-ordination problem	Subsidize production and implementation of technologies
Growth Phase (diffusion) This represents market penetration through acceptance of the innovation by potential users of the technology. But supply and demand side factors jointly influence the rate of diffusion.		Slow adoption • Institutional barriers • Access to finance	To create a technology push • R&D support • Financial incentives • Procurement initiatives • A carbon tax on fossil fuels • Production tax credit • Low interest loan
Commercialization of a new product, material or process with potential for immediate utilization. Depends on technical, economic factors etc.		Capital constraints Simultaneous coordination problem	• Production tax credit • Renewable portfolio standards (RPS) • Investment subsidy to solar panel & wind turbines in USA • FIT • Public Utility Regulatory Authority in USA to purchase RE at a price not higher than their avoided costs to promote RE • In Germany RE prices (for producers) were tailored to each type of RE since each technology faces different cost of generation • Netherlands enacted Demand pull eco-tax: producers of RE receive production subsidy & households are exempt from eco-tax on RE
Adoption	Behavioral issues • Consumer myopia • Cultural issues • Information gaps • Split incentive issues	Capital constraints Simultaneous coordination problem	• Capital subsidies • Soft loan • Labelling • Regulatory standards • Tax incentives

Source: Authors

2.3 Guiding Principles Underlying the Choice and Design of Instruments

This section discusses a broad framework of basic guiding principles underlying the choice and design of instruments with emphasis on relative merits of specific instruments on identified performance criterions. These discussions draw from the theoretical literature as well as from select literature on recent country experiences and thus serve as a lesson for designing and implementing CFPI. It is important to note that these discussions and resulting suggestions should be seen in light of the fact that there may be a large number of other policy and general business environment related factors in individual countries informing as well as influencing both the design and the performance of a policy.

Choice of policies

Although a number of considerations, with significant overlap among them, would determine the choice and design of technology policies, there are some general rules at the theoretical level.

- Enhancement of economic efficiency[12] would be the primary criterion thus policies should be targeting the identified externalities. Certain technologies may require special consideration though. For example, breakthrough technologies such as CCS which may have the potential to produce dramatic results (Fischer and Newell, 2007). However, CCS is very capital intensive with lot of uncertainty about its long term impacts. Therefore a policy mix incorporating preferential capital, international collaboration, among others, will need to be designed (IRENA, 2013).
- The choice of appropriate policy instruments will also depend on how optimal the policies dealing with GHG emissions are? For instance, in the presence of a sub- optimal emission policy − such as when emission pricing is just a token (e.g. a tax on carbon emissions with no link to emission reduction targets in a country) and/or covers only a few sectors of the economy − the role of CFPI can be seen as a way of correcting negative environmental externalities resulting from the use of fossil fuels and of addressing market failures in the low-carbon energy technology market, whereas in the presence of an optimal emission policy along with a clear roadmap to fossil fuel subsidy reform, the role of CFPI can be seen as a way of achieving dynamic efficiency by stimulating technical change. (Fischer, et. al 2012).
- Even with strong emission policy, certain technologies that require large capital investment and must scale up to realize cost reduction are likely to face barriers, if there are capital constraints or a simultaneous coordination problem. Capital constraints are more significant in emerging economies which lack venture capitalists, and private equity institutions (Gillingham and Sweeney, 2012). Targeted policies will thus need to be brought into play.

In addition, a number of other factors will determine the choice of instruments

a. Status of many critical factors such as skilled manpower, R&D capability, strong supporting institutions and capacity for developing systems for price discovery (e.g. auctions, reverse bidding) significantly influence both the choice of CFPI and their impact.

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[12] Gillingham and Sweeney (2012) pointing to a variety of different barriers to the implementation of low-carbon technologies argues that enhancement in economic efficiency should be the primary criterion for policy design and thus not all market barriers provide a rationale for policy intervention.

b. Availability of empirical evidence on contribution of specific market failures (relative importance and magnitude of AP and LBD) on technology development/penetration/adoption (e.g. despite vast empirical literature, considerable uncertainty remains regarding LBD for a wide range of technologies (Doner, 2007)).

c. Policies enacted at sub-national/state level should be in agreement/co-ordinated and consistent with national policies and goals.

d. Maturity of clean energy market, regulatory provisions such as long term policy and financial commitment, and targets for clean energy is some other important determinants of CFPIs.

Design of policies

The most important aspects of designing technology policy are the determination of the support level and the duration of the support. This is more complex than it may seem. For instance, policy instruments that would effectively promote basic R&D are different from those needed to stimulate dynamic learning process and bring down the cost of technology. There are knowledge spillovers at both stages of innovation, but for practical decision making, there is still a knowledge gap on demonstrating empirically how such knowledge spillovers contribute to hampering the development of different clean energy technologies. Further, there is limited understanding on how policies designed to address different priority issues play out through interactions.

- From an operational perspective what is crucial is to design a framework for providing and then phasing out these policies/schemes. This, among others, would require a better understanding of market dynamics and the change of policy impacts due to policy interactions. To this end, incorporating feedback loops, learning by doing, information diffusion are needed. Policy mix models combining the top-down and bottom-up perspectives in energy modeling will also be required. Equally important in this context is research which will feed information into estimation of these data intensive models. Good source of data or readily available data on many variables for short time periods are yet hard to come by. This is partly due to the fact that the efficacy of some of these instruments is beginning to emerge especially in emerging economies.
- Comparative efficiency of different policies is equally important which must take into account the characteristics of innovation process and adoption conditions. Different criteria (incentive to stimulate technical progress, incentive to stimulate dynamic learning process, cost to the economy, and capacity to stimulate capacity addition) have been used in understanding the impact of technology instruments. It may not be prudent to judge policies based only on theoretical argument. Information on policy details and the local environment are important in understanding how the policies work on the ground. This information is limited.
- It is important to make policies predictable, stable in medium to long-term to reduce the risk and uncertainty that investors and consumers face. Production Tax Credit for wind turbines in USA which had to be periodically renewed caused large fluctuations in wind capacity as opposed to consistent yearly growth of the wind industry in Denmark which provided direct subsidy which remained unchanged for many years (Doner, 2007).
- For some technologies there may be need for policy intervention in the early stages of market transformation to remove market barriers, which will increase sales of new

technologies and through learning and scale economies will accelerate the reduction in per unit costs. This results in a positive feedback loop that can lead to rapid market growth (Doner, 2007). The key message in this research is that you should take into account these feedback loops, such as learning by doing, and information diffusion when designing a policy/phasing-in the incentives. These are important in determining how to distribute the subsidies to both accelerate the diffusion and optimize the total subsidy. This was supported by an empirical study for Germany (Lobel and Perakis, 2011) which shows that stronger subsidies in the beginning, and a faster phase-out would have been more cost efficient in Germany.
- Capacity for developing systems for price discovery (e.g. auctions, reverse bidding) and to be able to use this information without much pressure on margins such that the delicate balance of risk reward ratio is maintained.
- A properly designed instrument would be: cost – effective and flexible, predictable, enforceable, consistent with market structure, and compatible with other policies.

2.4 The Comparative Efficiency of Different Policies

The following criteria are suggested in analyzing the impact of different CFPI (Menanteau et al 2003):

- Capacity to stimulate RE generation
- Incentives to reduce costs and prices
- Incentives to innovate
- Overall cost to community

It may be noted that while the above mentioned aspects of policy design are important, in this respect creating a positive business sentiment through reliable, transparent and fairly long term policy commitment on the part of the regulator has been emphasized (Hass et al 2008, and Sawin 2004). The literature also outlines that a policy mix will be required to include specific policies targeting RE in general and possibly another layer of policies targeting specific RE technologies differentiated by the stage of innovation.

Table 6 presents relative merits of some policy instruments on these criteria. As a general point, in the case of pollution control methods price based (P) and quantity based (Q) schemes produce similar results, when all the necessary information is available. However, these two approaches will not produce similar results when information is incomplete (Cropper and Oats, 1992). One or the other of these will be preferred depending upon the abatement cost curve and the damage curve (Weitzman, 1974). In application of these concepts in the case of stimulating low-carbon energy generation a simplified argument would be that a Q based approach[13] would be preferable

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[13] In a Q based approach regulator defines a reserved market for a given amount of RE and organizes a competition between producers to allocate this amount. Competitive bidding system limit the margin with respect to risk and thus may result in much more limited installed capacities. But, under a bidding system, the level of subsidies for renewable electricity generation can be controlled unlike the case of feed in tariff.

Table 6: Criteria for Choice and Design of Instruments

Instrument	Design	Incentive to reduce cost & prices	Effectiveness in stimulation to RE generation	Stimulation of technical change	Cost to community	Remarks
Feed – in – Tariff (Price based systems)	Government sets a price and markets determine the quantity of RE at that price. Effectively it involves a subsidy to the producers of RE. Whereas a regulation (RPS) makes it obligatory for the electric utilities to mix RE in its portfolio.	No incentive to producers; government has no direct control on Q; Governments have introduced a provision to gradually reduce FIT to take account of progress in RE technologies. FIT does not encourage innovation because of guaranteed prices.	• Reduces risk for RE developers. Thus encourages capacity generation. • Low risk and transactions cost and potential to reduce costs provides strong incentive to add more capacities. • Has better L-R effects are promoting wind energy.	• Increase in installed capacities lead to cost reduction and consequently improved margins. This enables producers to invest in R&D. • Strong incentive to invest in R&D to consolidate their industrial base. • Strong incentive to producers and manufacturers who would benefit from reduced costs and thus higher surpluses.	• Costly in terms of subsidies but simple to administer • Q can exceed the targets. • Support for RE is unrelated to electricity price charges.	• Useful in supporting certain technologies that may have potential but not fully developed thus expensive. • Useful if the objective is to develop local manufacturing and other capacity for installation and servicing. Potential benefits employment and export earnings.
Reverse auctions FIT	This system was a competitive process to award its FIT entitlements assessed on multiple performance criterion including the price. In this scheme government sets a Q and markets determine the FIT price subject to a performance assessment.	No incentive to producers to reveal cost reduction	• Revenue certainty leads to investment in capacity. • Bidder pre-qualifications assessment is important to ensure capacity generation is delivered.	• Incentive to reduce EPC capital cost.	• Subsidy can be controlled. • Significant transaction costs.	• Cost effective in the case of established technologies.
Competitive bidding	Government sets a quantity and organizes competitive bidding from RE producers to allocate this amount at prices determined by them. Electric utilities and obliged to purchase	• Strong incentive to producers to cut production costs	Limited margins with respect to risk will result in limited capacities.	• Relatively their margins limited R&D below optimal. • Surplus generated from reduced costs is shared among producers, manufacturers, and consumers/tax payers • Incentive to reduce EPC	• Through indirect controls level of subsidies can be controlled. • Significant transaction costs. • Support for RE is unrelated to	• Prudent in the case of established technologies.

	RE from selected RE producers.			capital cost	electricity price charges.	
Green certificates (Quantity based approach)	Green certificates are attributed to RE generators who sell power at wholesale market prices; and sell certificates to operators who have a particular quota to meet under this system RE generation objective are imposed on retailers/distributors for allocation efficiency when they have access to different resources.	Strong incentive to control both equipment and operating costs.	More adapted to liberalized energy markets.	Strong incentive	• Potentially the most efficient way for distributing the overall RE target among several technologies and organizing RE development on a large scale. • Costs are distributed equitably among consumers. • This system makes it possible to use least cost source for a single technology (such as wind before PV). But may prevent investment in promising but has developed technology.	
RPS	Renewable Portfolio standard is structured as a quantity regulation, letting the market determine the price for RE. Governments set targets to ensure a certain mix of RE in total generation capacity. In most cases REC are created to track the performance. RECs allow for trading in the market as	Strong incentive, as RPS can potentially incentivize competition among different RE technologies.	Could provide incentive to producers in S-R Provides incentive to utilities to either produce RE or buy REC. A properly designed RPS and well-functioning REC markets are required. This implies a long-term policy and targets on RE and strong regulator	Likely to create a competitive environment for all RE technologies and thus provide incentive to R&D.	Flexibility of RPS allows generators to comply at least cost.	For wind E cost curve is relatively flat so Q instrument would be superior to price investment. In the case of wind E, RPS is a market based system and thus favored over FIT according to Environmental Economics theory arguments; as FIT is subject to price control.

	penalties are imposed for non-compliance.					
Investment Subsidy	Directly reimburses the capital investment on equipment or total capital cost of the project.	No incentive to producers	Strong incentive (Key to growth in WE in Denmark)	May be	yes	• Useful in supporting certain technologies that may have potential but not fully developed thus expensive.

Source: Authors

when the slope of the MC is relatively flat. Conversely, a P instrument such as FIT[14] may lead to significant increase in supply and consequently in subsidies.

It can then be argued that the Q based approach is the more effective in controlling the cost of government incentive policies whereas in P based systems (e.g. FIT), production cannot be anticipated with any precision because of the uncertainty regarding cost curves. Therefore, if the emphasis is on fast pacing the RE generation and also keep a check on the cost of subsidies the policy maker should choose a combination of the Q (e.g. RPS) and P instrument such as competitive bidding system[15] which provides incentive to reduce costs *vis-a-vis* FIT, since competing producers must reflect lower costs in prices in order to win subsidies. However, this may or may not work for all types of technologies. Dong (2012) finds that FIT has better long term effects in promoting wind energy, although in short-run RPS could also provide some incentives to developers.

However, a cautious approach would be required. For, it may be argued that bidding approach lowers price and cost of RE though this price reduction may not be due to technical change but may happen due to systematic effort to reduce costs through economies of scale and use of the very best sites available. In terms of efficiency in the price vs quantity debate whatever system is chosen, the main objective in the medium to long-term in most cases will be to stimulate technical progress such that the gap between the costs of low-carbon energy and existing technologies continuously narrows down.

Empirical research shows that the technological learning effects have been much greater for manufacturers in countries that have opted for FIT (Dong, 2012). An explanation would be that the surplus that goes to the producers in Q based approach is limited whereas technical change tends to increase the producers' surplus in the case of P based approach (e.g. FIT), thus encouraging them to innovate more.

According to Menanteau et al (2003), if social preference is attached to climate change prevention and reflected in a high quantitative objective for RE, FIT is a good compromise in order to promote technical progress. The quota/certificate system also presents a number of advantages in terms of static efficiency, but its ability to stimulate innovation still has to be confirmed by experience.

Madlener et al (2010) considering a perfectly competitive market with a possibility of technological innovation, contrast guaranteed FIT for electricity from renewable with traded green certificate from the point of view of social welfare as well as that of dynamic efficiency. In terms of social welfare, subsidy and quota policies are shown to be equivalent as in the static model. The main finding is that subsidy policies are preferable in terms of dynamic efficiency.

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[14] A FIT is a policy mechanism where eligible renewable electricity generators are paid a cost-based price for the renewable electricity they supply to the grid which ensures that investors get guaranteed income that covers costs and also get additional return on capital sufficient to motivate investment. A differentiated tariff approach attempts to give each producer what it required to maintain production so that the optimal market quantity of renewable energy production can be reached.

[15] CB schemes allow indirect control on public expenses through successive quotas. However, transaction costs for both producers and government are lower in FIT vis-à-vis CB.

However, the P approach dominates the Q approach in terms of social welfare if the assumption of perfect competition is relaxed.

The criterion of the dynamic efficiency of the incentive instruments enables the approach to be extended beyond examining simply the effects of reduced costs over a short period. Dynamic efficiency (establishing sustainable technical progress) has two components. The dynamic process in part on the technological learning process related to wider diffusion of the technologies; and on manufacturers' R&D investments and thus on surpluses that might be generated. Thus if the objective is to encourage local R&D to achieve the goal of developing a competitive RE industry, some protection to the domestic industry will be required before it can be opened to the external competition. A FIT system will be helpful in such a situation (This is evidenced by the fact that Germany, Denmark, and Spain are the world leaders in wind turbine production).

Green Certificates will be more compatible with the liberalization of the electricity market in various countries. The system of tradable green certificate is similar to Q based mechanisms but differs from a bidding system in that each operator is assigned quantitative objectives. The potential advantages of green certificate trading system is that the goal of new energy generating capacity can be achieved in a cost effective way by distributing the overall objective among several technologies. But given the limited experience with green certificates, and a number of challenges (e.g. risk of small number of participants, risk of price volatility, other transaction costs, creation of floor prices, ability to enforce penalties (due to complex market structure and political infeasibility on defaulters) its real efficiency has still to be proven (Fristrup, 2000). A framework to redistribute funds collected through penalties will contribute in improving the acceptance of investors.

3. Public Policy Mechanisms Available to Policy Makers

A broad range of policies have been implemented to address environmental and knowledge externalities and can be listed as below:

(i) Taxing fossil fuel-based energy or pricing carbon emissions (a carbon tax or through cap and trade) to make it expensive thus incentivizing the energy producers to reduce emissions intensity, and consumers to conserve energy. By making low-carbon energy technologies cost-competitive, carbon pricing incentivizes their adoption and, in turn, stimulates investment in these technologies (Box 5).

Box 5

A carbon price has sizeable effects on low- carbon energy R&D and technology deployment (Bosetti et al, 2009). For instance, the study shows that the WITCH model's (inter-temporally optimal) world carbon price path to stabilize long-run CO_2 concentration at 450 ppm and overall GHG concentration at about 550 ppm CO_2eq is estimated to induce a four-fold increase in energy R&D expenditure and investment in deployment of renewable power generation by 2050, compared with the baseline scenario. These effects increase over time and/or as concentration targets become more stringent, reflecting a higher CO_2 price.

The study also finds that expectations of future carbon prices and, therefore, the credibility of future climate policy commitments, matter a great deal for today's investment in low-carbon R&D and technology deployment. For instance, under similar carbon price levels, R&D investment is found to be noticeably higher under a 550 ppm CO_2 eq. GHG (450 ppm CO2 only) concentration stabilization objective than under a 650 ppm CO_2eq (550 ppm CO2 only) scenario, reflecting higher expected future increases in carbon prices. The study concludes that R&D alone is not an effective option to address climate change.

Fischer and Newell (2007) find in the absence of any price to GHG emissions, technology support policies do not provide a cost-effective way to stimulate innovation and technology diffusion. The study finds R&D subsidies to be the costliest policy option to reduce emissions from electricity production, followed by RE adoption incentives, emissions performance standards and emissions pricing.

However studies by Jaffe and Stavins (1995) and Hassett and Metcalf (1995) find larger effects from technology cost subsidies than from energy taxes on EE improvements in USA

Many countries have successfully implemented carbon pricing policies. Yet, no country has implemented economy-wide optimum carbon pricing[16].

(ii) Although carbon pricing/trading would provide some R&D incentives but cannot simultaneously address the multiple market imperfections involved in achieving cost-effective GHG emission reductions. Therefore, overall mitigation costs may be lowered by combining policy instruments according to their comparative advantage in addressing each market imperfection (Box 6).

Box 6

For instance, based on a theoretical model calibrated on US electricity sector data, Fischer and Newell (2007) suggest that optimal R&D and renewable subsidies could lower by over a third, the CO_2 emissions price needed to achieve a 5% cut in US electricity sector emissions, and could bring down the overall cost of the policy package to zero, due to the positive spillovers generated by the technology-support policies.

Polices focusing on reducing the cost of research and development (R&D) in low-carbon technologies such as a tax credits, investment tax breaks (accelerated depreciation etc.), subsidy for capital costs (grant, soft loan), institutional support (government funded research facilities, support for getting patents) and stricter patent rules thus have an important role to play in incentivizing investment in R&D and thus lowering the cost of low-carbon energy technologies.

(iii) Besides the policies that deal with general innovation and diffusion failures/barriers, the policy makers would need policies to address those innovation and diffusion failures that are specific to low-carbon energy technologies through technology adoption instruments (e.g. supporting RE generation (ensuring viable markets) through a subsidy (feed-in-tariff (FIT)) or production tax credit, in USA, or RPS (creating market share) requirement).

A suggestive framework for Public Policy mechanisms through five different stages of the technology continuum is in Figure1 (see Section1.1). This framework not only differentiates a whole basket of policy instruments between regulatory, fiscal and financial instruments but also by different stages of innovation and at the same time provides a suggestive link between the primary objectives through various stages of innovation. The lessons learnt from the design and implementation of these policies finds a more detailed discussion in Section 4.

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[16] At present only about 12 % of global GHG are priced, and prices (e.g. in the EU) are well below what is needed to reflect environmental damages or be consistent with long term climate stabilization goals.

3.1 Defining CFPI for the purposes of this study

Broadly, fiscal policies commonly refer to tax and public expenditure based measures such as accelerated depreciation; tax holidays for initial years of the project (post-commissioning); tax rebates through waiver/reduction of import duties and excise duty (tax on production of goods); and capital subsidy (grants, soft loans). They are, invariably, based on the size of the investment/actual installation of the equipment; they are not linked to the use or performance of the equipment. There may be some (e.g. tax incentives and subsidies for projects in designated areas/special economic zones etc.) that are not linked to the actual activity, use of specific technology and quantum of power generation.

Financial incentives, on the other hand, are (mostly) directly linked to the actual amount of generation and in some cases on the amount of investment, e.g. policies such as FITs, generation-based incentives (GBI). Financial instruments are often designed to address financial barriers, such as access to capital, high perceived risk to the sector, etc.

UNEP (2011) defines public finance mechanisms (PFMs) as financial commitments made by the public sector that alter the risk-reward balance of private sector investments by reducing or removing barriers to investment. It further states that while policy instruments that set the overall economic framework conditions for investment in low-carbon technology such as FITs, carbon taxes and renewable portfolio standards (RPS) are not regarded as PFMs, their presence has a significant effect on the success of a given PFM. They should therefore be taken into account when evaluating the context in which successful PFMs operate.

In this study CFPIs are taken to be a combination of supporting regulatory policy and tax mechanisms, and PFMs to support investment in low-carbon energy technologies. This is because of the interdependencies (e.g. presence of RPS can enhance the effectiveness of FIT) between them and the fact that different types of instruments are required along the low-carbon technology continuum (Figure 1).

3.2 ***CFPI differentiated into market-pull and technology-push policies***

While the demand-pull policies aim to increase the RE demand by addressing environmental externalities or reducing market barriers, technology-push policies primarily aim at increasing the incentives to generate new knowledge and further work on the available knowledge to improve upon its performance and cost. This differentiation is helpful in identifying the right instrument and its appropriate design. Table 7 presents a broad categorization of these.

The technology-push policies can be classified into fiscal measures (e.g. grants, rebates, tax credits), financial measures (e.g. direct investment, soft loans, credit risk guarantees etc.), institutional support (government funded research facilities, support for getting patents) and stricter patent rules to reduce the upfront costs and risks of investments (Mitchel et al 2011). These directly target and incentivize the private investment in various stages of technology development and diffusion. Technology-push policies are especially important in pushing investment in early stages of innovation due to various risks and uncertainties around the chances of success and the time taken in reaching the commercial stage.

Market pull policies include both quantity based (e.g. carbon trading mechanism, RPS); and the price based (e.g. carbon tax, FIT) instruments which can be either technology neutral (e.g. carbon tax, carbon trading mechanism) or target specific technologies (e.g. FIT, RPS).

Although overall efficiency of technology-neutral versus technology-specific policies has been a subject of considerable debate; empirical evidence on limited impact of EU ETS on innovation

Table 7: Strategies and selected policies for promotion of RE

Market-pull policies				
	Technology-specific (direct)			Non-technology-specific (indirect)
		Price-driven	Quantity-driven	
Market-based	Investment incentives	• Investment subsidies • Tax credits • Supportive tax policy • Tenders (prices)	• Tendering systems for investment grants (quantity) • Quotas (capacity)	• Environmental taxes • Emission trading
	Generation incentives	• Feed-in tariffs • Premium feed-in tariffs	• Energy portfolio standard (quotas) in combination with tradable green certificates • Tendering systems for long-term contracts	
Command-and-control		• Technology and performance standards • Authorization procedures		
Voluntary	Investment Promotion	• Shareholder programs • Contribution programs		• Voluntary agreements
	Generation promotion	• Green tariffs		
Technology-push policies				
	• Public R&D spending (direct funding, grants, prices) • Tax credits to invest in R&D • Capacity enhancement for knowledge exchange • Support for education and training • Financing demonstration or pilot projects • Market engagement/incentive programs/public procurement • Strategic development policies • Technology exhibitions/fairs • Network creating/building			

Source: Groba and Breitschopf (2013)

(Schmidt et al 2012, Rogge et al. 2011) points to the need for additional technology specific policies. A useful taxonomy of RE (solar PV and wind power) enabling direct and indirect policies and programs is in Annexure B.

As a general rule, policies such as research and development support, financial incentives, and procurement incentives are appropriate for stimulating commercialization and initial markets for new technologies which can create a technology push. Once a technology is established in the market further growth can be stimulated by policies such as FIT, RPS and other financial incentives.

An important issue however is to strike a balance between technology- push and market-pull measures from the beginning. To do so, policymakers need to understand how these measures interact under and respond to different market conditions[17]. This however is an area for future research although some discussion on this is available in Dong (2012) pointing toward more empirical research on structural reasons for a country to adopt a given policy. This should be done in a technology, country and a case specific way.

4. Design and Implementation of CPFI: Best practices and lessons learnt

This section is set at identifying the best practices associated with the design of the instruments as well as the main lessons learned of the implementation of RE and EE policy tools. In what follows immediately, the policy environment for RE development and deployment is presented. This provides the context in which the discussion on the best practices and lessons learnt with regard to individual RE policy instruments is placed.

4.1 Policy context in which RE technology (RET) development and deployment incentives have emerged

It is important to understand the policy environment in which measures towards promoting RET development and deployment have emerged in developed and developing countries. This helps understand the context in which specific factors have proved conducive to or barriers to effective dissemination of RETs. On the one hand, a strong political will and compliance with international treaty/ agreement has favored the development of RETs, on the other, planning and bureaucratic hurdles and grid connection issues have hindered their effective deployment. Policy design and implementation can also be linked to the market structures in the economy. The discussion below is elucidatory, for which a country-wise summary is also tabulated in Annexure C.

Foremost, it has been the presence of a *clear political resolve* that has led to the successful design and implementation of policies and support measures for encouraging renewable energy technologies. In China, for examples, a world leader in non-hydropower RE capacity (at 70 GW at the national level by 2011), and additionally having installed more wind turbines and manufactured more solar PV panels than any other country in the world, the impressive growth of RE capacity (from 27.8 Gigawatt (GW) in 2001 to 183 GW in 2013, with share of RE to account for 20% of aggregate electricity generation in the country by 2020) can be ascribed to a clear political will, combined with an aggressive pricing mechanism and a strong manufacturing base to back this process. In 2006, the government has established a renewable energy law that has articulated time-bound goals and objectives for renewable energy development and

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[17] For a discussion on interaction among policy instruments for GHG emissions-reduction (e.g. carbon pricing, carbon trading etc.) see Sorrell, 2002; Sorrell and Sijm, 2003.

deployment. These were aided by complementary measures toward diversification of the energy mix, development of a strong indigenous manufacturing base, putting in place an aggressive incentives mechanism. Support instruments instituted by the National Development and Reform Commission (NDRC) of China included reliance on competitive bidding system and subsequently, in 2009, a move to feed-in-tariffs, differentiated by wind energy resources. Companies than won the bid were provided guaranteed grid access through a power purchase agreement, coupled with a range of complementary measures such as preferential loan and tax conditions, and financial support for road and grid extension (WWF and WRI, 2013). Despite the stupendous success, sustaining this performance poses a difficulty for China on account of grid connection issues, not merely in terms of physical constraints but also as a political challenge (WWF and WRI, 2013).

Germany too exhibits a strong and steadily rising share of RE in the electricity, heat and biofuel sectors. In 2012, renewable energy generation, including hydropower, accounted for 23.5% (140,000 GWh) of total power consumption in the country, up from 11% percent in 2005 and a mere 4.3% (19.000 GWh) of total power consumption in 1990. In 2000, the Erneuerbare-Energien-Gesetz (Renewable Energy Sources Act – EEG) was made effective, which has been the primary instrument for the promotion of RE in the electricity sector of Germany. The EEG received immense support from parties across the entire political spectrum of the country. RE development was incorporated as an integral part of the industrial development policy, complemented by Germany's commitment to shift from nuclear and fossil fuels to renewable. Specifically, the key policies driving the dissemination of RE are the German Renewable Energy Law (EEG) in the case of RES-E, the market incentive program for renewable heat generation and the tax exemptions in the bio-fuel sector. The highest growth in terms of total installed power capacity has been for wind power, with biomass energy based growth (especially bio-fuels and biogas) having increased in the last few years. The success of the EEG can be attributed to a stable flow of investment, priority grid access and sufficiently high feed-in-tariffs for renewables. The market incentives have also stimulated the RES-H market, but this application has faced some budgetary restrictions (Jager and Rathmann, 2008).

As distinct from a strong domestic political steadfastness, sometimes, the growth of RETs can be ascribed to *countries' compliance with international environmental treaties*. Canada is a case in point. So far, the development and deployment of RES in Canada is largely confined to hydropower and some biomass. Since the late 1990s, a number of support policies and measures were instituted by the federal and provincial governments, but these have not been adequate to stimulate significant RE development. It is post the adoption of Kyoto Protocol in December 1997 that policy and measures supporting RE investment and deployment were introduced in Canada. Prior to this, the efforts were concentrated on competitive technologies such as large hydropower and biomass for application in paper and forest product industries. Recently, the key support instruments that have been put in place at the federal government are a (rather low) feed-in premium for almost all RES-E technologies and flexible depreciation on investment cost. Conditional on the specific project, complementary instruments have been used, such as investment subsidies and low interest loans. Some provinces also rely on additional instruments that may be necessary to ensure financial viability (Jager and Rathmann, 2008).

Presently, the RE development and deployment in India is guided by the targets laid down in the various national Five Year Plans (FYPs), the National Action Plan on Climate Change (NAPCC) and the Jawaharlal Nehru National Solar Mission (JNNSM). Thus, the driving factors in India have been a mix of national policy resolve and requirements placed by the international treaties. The 11th FYP(2007-2012) set a target of additional 12.4 GW of grid connected RE that was exceeded with actual installation being over 14 GW during this period (ABPS Infra, 2009). The target set for the 12thFYP (2012-17) is 30 GW of RES-E with the following mix of technology: 15 GW wind, 10GW solar and 2.1 GW of small hydro (Government of India, 2013).The NAPCC was launched in 2008 and envisages around 15% electricity consumption from RES by 2020. Under the umbrella of NAPCC, the JNNSM was initiated that sets out a target of 22 GW of solar capacity by 2022 in both grid- and off-grid modes. It also proposes an integrated approach to policy support, including support toward R&D, manufacturing development and market deployment (EPIA 2012, MNRE (GoI) and WWF and WRI, 2013). So far, in India, reliance has been placed on both quantity and price based measures, namely RPO scheme with tradable renewable energy certificate scheme and feed-in-tariffs for all RETs. Despite the impressive growth, India continues to face the challenge of broad basing RE development and deployment as, so far, this has been restricted to select states. Strengthening of transparency and accountability for RPSs and targets and need for greater attention to grid connectivity issues pose a challenge.

Again, in Japan, it was the National Energy Law (1997) that specified the target for RE in aggregate primary energy supply. This was supported by renewable energy promotion rules for on how the costs of grid reinforcement should be borne, and how the transmission network should be improved and maintained (Jager and Rathmann, 2008). RES-E has generally relied on support from a Renewables Portfolio Standard (RPS) scheme that was launched in 2003. RPSs have been implemented for a range of technologies, namely offshore wind, onshore wind, solar PV, solar thermal electric, CSP, biomass, small hydropower and geothermal. Of the modest target set for the proportion of RE in power generation, a large part is to come from solar PV, wind power and municipal solid waste. Besides RPS, voluntary agreements between government and energy suppliers to buy electricity generated from RE at the residential retail price (suitable feed-in-tariffs) introduced in 1992 were also significant determinant of power generation from RE until 2002. Solar PV plays an important role in the Japanese power system. The financial support for PV has been mainly aimed at RD&D schemes. In the past, the thrust on development of PV cell technology was achieved mainly through the Moonlight and Sunshine Projects in the 1970s and 1980s. The support for RD&D continued with the New Sunshine Program, which came to an end in 2000. The aim of the subsidy program for residential PV systems that ran from 1994 up to 2002 was to promote the development of PV systems.

Complex administrative and planning procedures and *grid connectivity constraints* have been a hindrance to realization of full RE potential. Due to this, there has been only modest development of RE in France in the recent past. Currently, the dominating RES-E technology is hydropower, although, there exists large potential for wind and biomass based energy. The French feed-in-laws are beset with complicated administrative and planning procedures that lower the realized potential of the incentives that have been put in place. There has been growing contribution from wind energy since 2006, and solid biomass has found an increasing use in the heating sector. RES support in France has been mainly provided through three instrument types: the feed-in tariff for RES-E, multiple tax reductions for RES in all sectors, and different subsidy programs run by French Environment and Energy Management Agency (ADEME). The specific structure of the scheme varies across regions and tends to be subject to frequent changes. Despite relatively high feed-in tariffs, RES-E and, especially wind energy development, has been hindered by bureaucratic planning regulations. The change of regulatory procedures in 2005 improved the situation, in that, in 2006, with newly installed capacity of 810 MW, France managed to more than double its market in wind power (Jager and Rathmann, 2008).

Similar constraints can be observed in Italy, where the production of RES-E from wind and biogas sources has displayed some increase, but this has not been commensurate with the growth of electricity consumption. The incentive and support measures instituted have been generally unstable. Moreover, the administrative procedures for grid connection have been long and complicated, entailing high transaction costs. During the 1990s, the most important incentive for penetration of RES-E was a feed-in-tariff. Since 2001, there was a move toward a quota obligation with tradable green certificates. In 2005, a separate feed-in tariff for solar photovoltaic was put into practice. A switch back to feed-in-tariffs for most technologies is imminent, which will replace the quota obligations. In spite of these measures, the development and deployment of RES-E has been disappointing – due mainly to political, administrative and financial reasons. Further, no specific national support instruments have been implemented for RES-H (Jager and Rathmann, 2008).

Spain exhibits an impressive development and deployment of RES-E technologies, especially based on wind and solar PV. The credit for the rapid development of the Spanish RE sector can be attributed to the legal framework (Royal Decree, RD) and the sustained incentive/ support schemes in the form of feed-in tariffs/ premium program (Regimen Especial). Steady systems of feed-in tariffs and premiums combined with low interest loans have provided high transparency and certainty in the market to the renewable energy project developers, especially wind and hydropower. In Spain, wind farms have been mainly developed and owned by consortia formed by utilities, regional institutions involved in local development, private investors and sometimes manufacturers. Grid connection procedures have been time consuming and barriers to further growth in wind capacity are constraints of dispatch ability and limited grid connection capacity.

Policy trends and performance are often found linked to size of the economy and the market structures therein. Azuela and Barroso (2011) find a clear distinction between large and medium-size countries (defined in terms of gross national income and size of power sector) in the variety of instruments found in the policy package. In general, Brazil, India, and Turkey have implemented a more diverse set of mechanisms to promote RE than Indonesia, Nicaragua, and Sri Lanka. Also, BRICS countries Brazil and India have been relying on more evolved types of instruments (well-developed FIT design, REC market, and auctions). Furthermore, the policies to support RE have been more effectual in the higher-income countries (Brazil, India, and Turkey). This could also be due to other complementary factors, such as the domestic investment climate, economic and political stability, and governance and institutional issues. In comparison, low RE market growth has been exhibited in both Indonesia and Nicaragua for reasons related to policy or contract design in combination with select external or background factors (such as regional financial crises, governance constraints, or regulatory uncertainty).

Against this backdrop, we discuss the country experiences with use of incentives and support measures for RE development and deployment.

4.2 Effectiveness and efficiency of support schemes for development and deployment of RETs: lessons learnt from country experiences

Designing policy for renewable energy programs requires choice of instruments based on many criteria – policy effectiveness in terms of stimulation of RE deployment, cost effectiveness indicators for the economy, incentive to reduce costs and prices and incentives to innovate/ technological learning or market maturation (Menanteau et. al., 2003). In light of these considerations, a discussion is now presented on how market deployment policy instruments for RE technologies have performed on, these accounts in terms of select country experiences (IEA, 2008 and IEA, 2011). The discussion provides useful insights on the lessons learnt from the impact of these economic support policies and forms the basis for dos and don'ts for future policy design and implementation.

Three key sets of support schemes have been taken up for analysis:

- *Price based market instruments such as feed-in-tariffs (FITs) and feed-in-premiums (FITPs):* FITs/ FITPs are one of the most widely used measures for promotion of RETs. These are price based regulatory instrument wherein producers are assured a set price or premium per unit of by the government for the electricity produced by them, irrespective of the amount generated. An important difference between FIT and premium payment is that the latter induces competition between producers in the electricity market. The public utility is obligated to connect the RE generator to the grid and pay a pre-determined rate/ premium for the life of FIT/ FITP contract, usually 10-20 years, to lower market risks to investors. The overall goal of the FIT scheme is to make way for the clean technologies by lowering the cost for the venturing firms for a fixed period of time, thus leading to the development of such resources and pave the way for further growth of the technology thereafter. Both FITs and FITPs are structured to stimulate specific technologies and cost reductions (latter though a phased reduction in tariff/ premium).
- *Quantity based market instruments called renewable portfolio standards (RPSs) or quota obligations:* RPS is a form of quantity regulation in which a target or quota obligation is set by the government in order to ensure that a set market share of energy (say, in the form of electricity) comes from RE sources (Dong, 2012). Here, a retailer is obligated to include energy generated by renewable sources into his portfolio. The obligated party failing to meet an obligation has to pay a penalty. Here, retailers and producers are the target of the policy as they are mandated to meet the obligation. Generally, RPS use tradable/ non-tradable renewable energy certificates (RECs) or tradable green certificates (TGCs) to create a market for environmental attributes (as in the UK) although this not always the case (as in California, US). A TGC is an official record certifying that a particular amount of renewable energy has been generated. Quota obligations with TGCs are generally technology-neutral support mechanisms, aiming at promoting most cost efficient technology options. Since an RPS relies entirely on the private market for its implementation, it tends to allow more competition among different types of renewable energy. Moreover, it permits RE sources to compete with the cheaper fossil fuels in the long run due to efficiency and innovation.
- *Tendering/ competitive bidding:* A tender is announced for providing a certain quantity of electricity from a certain technology source, and the bidding process ensures that the lowest offer is accepted. The structuring of competitive bidding can range from a single bid or multiple rounds of bid. Under the single bid arrangement, power producers bid for providing

a fixed amount of renewable power, and the lowest price-bidder wins the bid. Under multiple rounds of bidding, there are multiple winners and with each successive round of bidding, the price quoted by the bidder gets reduced, thereby reducing the cost of renewable energy (Beck et al, 2004). Tendering allows for incorporation of additional conditions, e.g. regarding local manufacturing of technology.

In what follows, the discussion focuses on the impact of policy support measures on stimulus to RES-E using the policy impact indicator (PII) and the cost-efficiency of the support scheme by relying on the total cost indicator (TCI), where both the indicators have been harmonized to allow cross-country comparisons. Both of these indicators are due to the International Energy Agency (IEA, 2011). In addition, the impacts studied in terms of other criteria include incentives to technology cost reduction and technology market maturation based on Jager and Rathmann (2008), which indirectly point toward incentive to innovate.

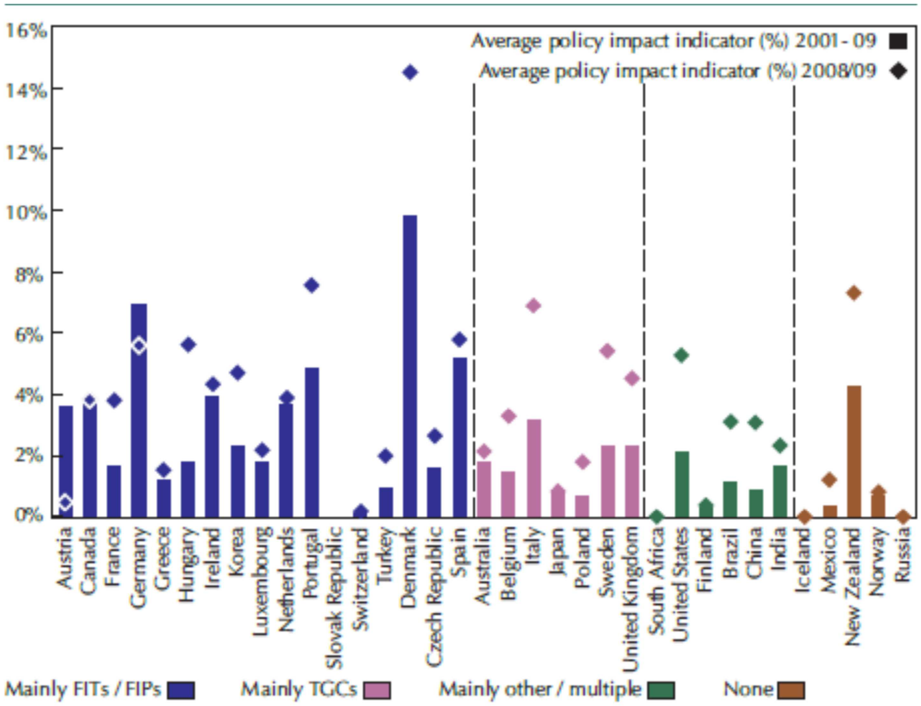
4.2.1 Stimulus to RES-E

The performance of the market deployment of a technology can be measured by the stimulus provided to RES-E. IEA has been relying on the PII for the OECD and BRICS countries, with focus on wind power and solar PV. PII measures the progress toward a defined goal and provides a measure of the impact of policies on stimulating deployment. It calculates the percentage of gap between the 2005 generation and the World Energy Outlook (WEO) 2030 target that was achieved in a given year. The indicator helps in comparing policy effectiveness across countries in stimulating the deployment for different technologies. The sample included 35 countries, of which 17 were using FITs, 6 were relying on certificate schemes and 5 were without policies.

4.2.1.1 Policy impact indicator for onshore wind

It was observed that for the entire span of period 2001-2009, the average PII in countries that have relied on FITs was 3.23%, 1.5 times of the level for countries using certificate schemes (at 2.1%). Of the ten countries with the highest PII, the top eight were using FITs (namely, Denmark, Germany, Spain, Portugal, Ireland, Canada and Netherlands), with New Zealand ranking fifth in the absence of a dedicated policy support. The only country amongst the top ten countries with reliance on certificate schemes was Italy.

Figure 3: PII for wind support policies in OECD and BRICS countries, 2001-09



Source: IEA, 2011

Interestingly, however, the difference in PII values has decreased between FITs and certificate schemes: the country average being 4% for FITs and 3.6% for certificate schemes in 2008-09. Of the top ten countries in 2008/09, six utilized a FIT (namely, Denmark, Portugal, Spain, Hungary, Germany and Korea) and two a certificate scheme (Italy and Sweden). New Zealand ranked third, and the United States ranked ninth (relying on federal tax credits and state-level quota obligations, some of them combined with a certificate system). Since merely 6 countries out of the entire sample of 35 countries relied mainly on certificate schemes, while 17 used FITs, countries using FITs cannot be considered systematically more effective.

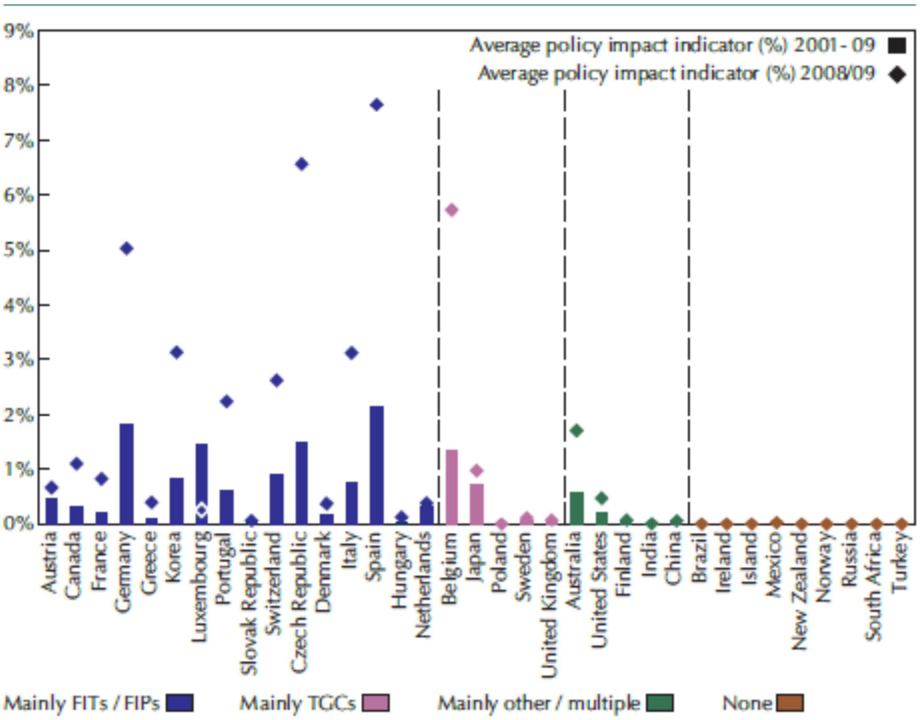
In general, the average impact of both FITs and certificate schemes has risen over time. But certificate schemes have displayed a stronger relative increase. In fact, based on 2009 data alone, TGCs systems fared even better than FITs (4.75% versus 4.36%). The reasons for this development could lie in a number of factors. First, the RE systems may have experienced strong learning effects and, more so in recent years. Another reason may be the low the baseline effectiveness of certificate systems to start out with: because many sites with abundant resources and available land still exist, deployment is easier after some level of learning has been attained. This conclusion is corroborated by the observation that two countries using a FIT and with high past effectiveness are now demonstrating lower levels (namely, Germany and Austria).

4.2.1.2 *Policy impact indicator for solar PV*

The comparative analysis of PII has been done for 35 countries of which 18 have been using FITs, 5 are relying on certificate schemes and the rest have other support policies in place. The average PII for countries using FITs is much higher (at 0.83 for the overall span 2001-09 and

2.13 in 2008-09) as compared to those relying on certificate schemes (at 0.43 for 2001-09 and 0.42 for 2008-09). Moreover, countries that succeeded in deployment of solar PV (with the exception of Belgium) used FITs to do so. This is due to the fact that certificate schemes objective is to use the least-cost options, implying that more expensive options (such as solar PV) do not witness significant deployment.

Figure 4: PII for solar PV support policies in OECD and BRICS, 2001-09



Source: IEA, 2011

In general terms, the policy effectiveness of solar PV deployment has risen overtime, as PV markets have evolved and matured over time. Moreover, FITs and FITPs have been most effective in stimulating PV deployment. In terms of country-wise impacts, five distinct categories can be identified (Figure 4).

The first group is countries that display little or no marked rise in PV deployment and have no dedicated support scheme in place, have very low support levels (namely, Brazil, China, South Africa, Mexico, Russia, Norway, Iceland, New Zealand, Turkey, Ireland, Hungary and Denmark). The second group exhibits very low levels of deployment, even though they provide substantial financial support. This is the case for India and, to a lesser extent, Greece (2010 effectiveness of 3.3%). Evidently, non-economic barriers are inhibiting larger growth of deployment in these countries. The third group displays a steady and smooth increase in policy effectiveness over time (as in case of United States, Japan, Switzerland and Canada) or an established effective policy environment (Germany). In contrast, the fourth group comprises countries that have seen a sudden jump in policy effectiveness (namely, Australia, Belgium, Italy, Austria, Slovakia, France and the Czech Republic). The last group witnessed a peak in effectiveness but then showed very low levels of deployment. This consists of Spain (where there was a boom in 2008, followed by a phase of market constraining in 2009 and 2010) and, to a lesser extent, Portugal and Korea (Figure 4).

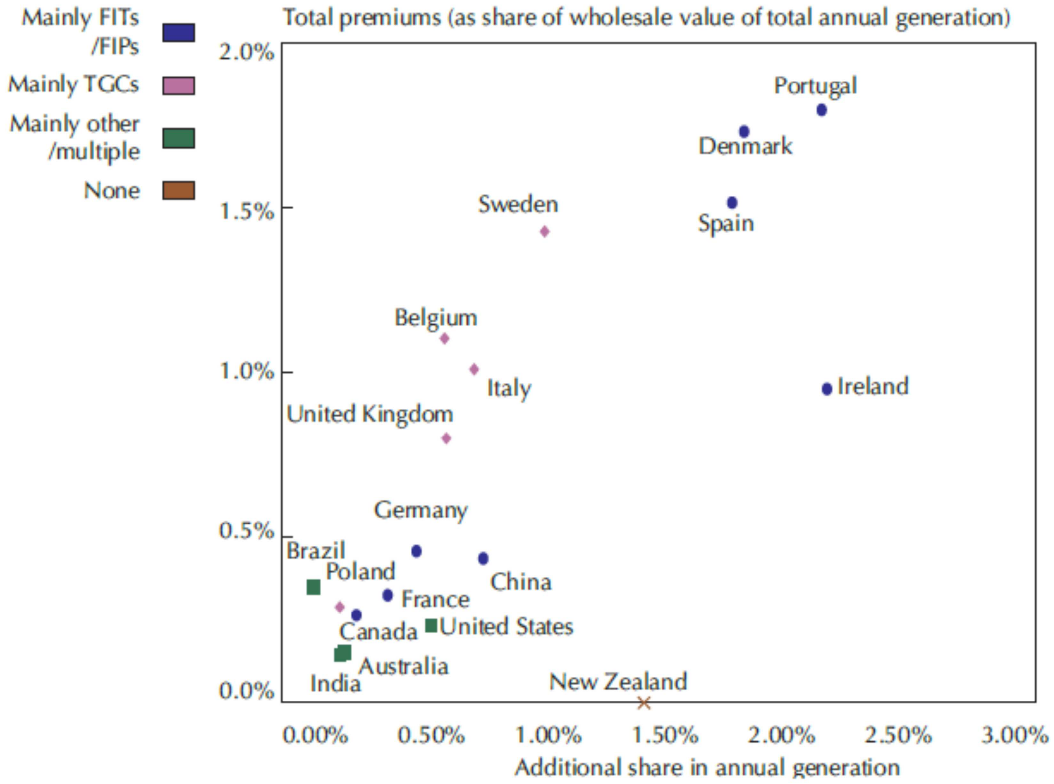
4.2.2 Cost effectiveness

As deployment volumes reach a large scale, a concern that has arisen relates to the overall cost of the policy to the economy in the form of support tariffs, premiums and subsidies. The varied types of power market structures render it problematic to assess the additional premiums that are paid on top of market price. Thus, IEA has attempted to quantify the total cost of policy support across the same group of countries, the total cost indicator (TCI), as for the PII. The TCI is defined as the amount of the additional annual premiums paid for an additional unit of generation per year. For normalization across countries, the annual premiums are expressed as a percentage of the total wholesale value of all the electricity generated. The TCI is plotted together with the share that the additional generation achieved in a given year has compared to total generation.

4.2.2.1 Cost effectiveness indicator for onshore wind

On a broader spectrum, countries show very large dispersion of total premium payments as measured by the TCI and a generally positive correlation between TCI and deployment of wind power. The lowest values have been exhibited by New Zealand, where no incremental premiums are required to be paid for the 1.5% of electricity that was covered by new wind generation in 2009. This is followed by India and Australia. Ireland too paid small premiums and displays low TCI for the extent of stimulus to wind power, while premiums were comparably large in Sweden, taking into account the smaller contribution of new wind. Portugal pays the highest total premiums for the wind power capacity that was deployed in 2009. This is why it also got a large amount from additional generation from wind power. Similar results were observed for Spain and Denmark (Figure 5). As can also be seen, FIT and FITPs exhibit a better trade-off than TGCs between wind's additional deployment and total premium costs.

Figure 5: Total cost indicator for onshore wind, 2009

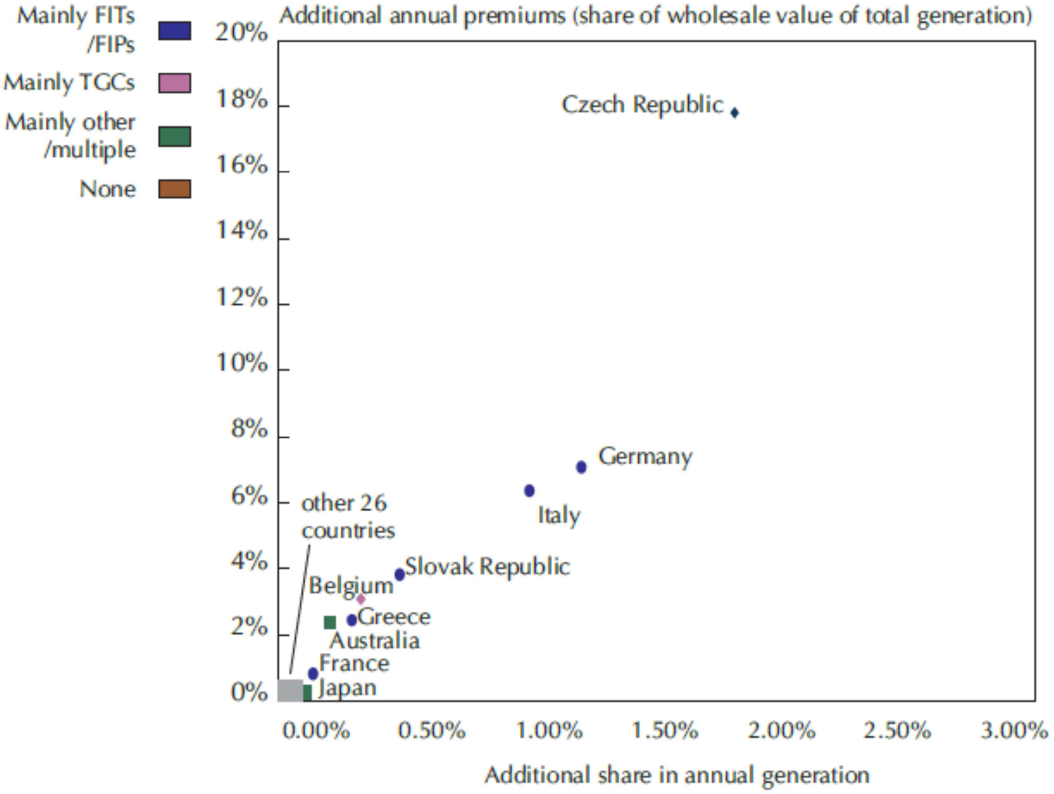


Source: IEA, 2011

4.2.2.2 Cost effectiveness indicator for solar PV

As the diffusion of some RE technologies such as solar PV are still in nascent stage of development of the learning curve, at large volumes of deployment, the total support costs indicators have come under policy scanner. In general, solar PV support deems it necessary to have payment of comparably high premiums. To evaluate the aggregate burden that support policies put on the national energy economy, the TCI was worked for the incremental generation produced in 2010 (Figure 6). Due to its relatively small size, combined with very high tariffs, the Czech Republic displays to the largest burden with respect to its overall power system. In comparison, this share is almost double of that for Germany. Also, compared to onshore wind, much larger premiums need to be paid.

Figure 6: Total cost indicator for solar PV in major markets, 2010



Source: IEA, 2011

4.2.3 *Contribution of scheme toward cost reduction for technologies and level of market maturation*

As discussed in section 2, in terms of static efficiency, the incentive to reduce costs is mainly experienced in the case of competitive bidding and TGCs (as the producers tend to be price takers). In comparison, the system of FITs/ FITPs does not provide the same level of incentive. However, once the dynamic effects are internalized in relation to stimulus to RES capacities (these largely operating through the effects of learning curves on cumulative production) FIT is likely to perform relatively better in terms of installation than competitive bidding or TGC systems. That the system that performs better dynamically is the one that stimulates RE market is corroborated by the data below (Table 8).

Table 8: Contribution of the support scheme to cost reduction of RES and level of market maturity

Country	**Instrument characterization**	**Contribution of the scheme towards reducing the costs of RES**				**Market maturity level**
		Wind-onshore	Wind-offshore	Combined heat and power biomass combustion	Solar photovoltaic	
Canada and Canadian Provinces	Production incentive	Insignificant	Insignificant	Insignificant	Insignificant	Moderately mature
Ontario	Feed-in-tariff	Significant			Moderately significant	Moderately mature
	Tax incentives					
	Competitive bidding: Tender (contract price)					
Quebec	Competitive bidding: Tender (contract price)	Significant				Moderately mature
France	Feed-in-tariffs	Significant	Significant	Significant	Significant	Emerging
	Competitive bidding:/ tendering					
	Tax measures					
Germany	Feed-in tariff	Significant	Significant	Significant	Significant	Fully mature
Italy	RPS (Quota obligation)	Significant	Significant	Significant	Significant	Emerging
	Feed-in-tariff	Significant	Significant	Significant	Significant	Emerging
Japan	RPS (Quota obligation)	Insignificant		Insignificant	Insignificant	Moderately mature
Netherlands	Feed-in-premium	Significant	Significant	Moderately significant	Insignificant	Moderately mature
Norway	Investment subsidy	Moderately significant	Insignificant	Moderately significant		Emerging
Spain	Feed-in-tariff/ feed-in-premium	Significant	Insignificant	Moderately significant	Significant	Fully mature
	Tax deduction					
	Low interest loan					
UK	RPS (Quota obligation)	Significant	Moderately significant	Moderately significant	Insignificant	Moderately mature
	Tax deduction	Significant	Moderately significant	Moderately significant	Insignificant	Moderately mature
	Investment subsidy	Significant	Moderately significant	Moderately significant	Insignificant	Moderately mature
US & US States	Production tax credit	Insignificant		Insignificant	Insignificant	Fully mature
California	RPS (Quota obligation)/ production incentive	Significant		Significant	Significant	Fully mature
Minnesota	RPS (Quota obligation)	Moderately significant		Moderately significant	Moderately significant	Moderately mature

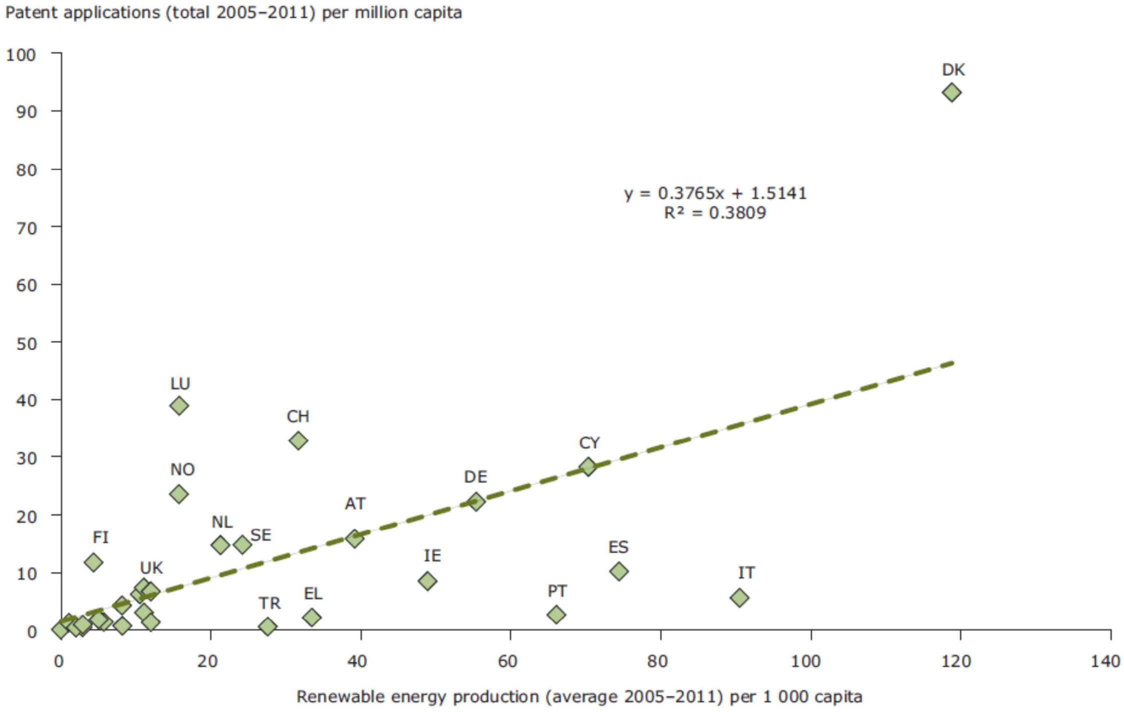
Source: adapted from Jager and Rathmann, 2008

As can be seen from the 2006 data for select OECD countries where the RE support policies have been in place for some time (these data are obtained by Jager and Rathmann, 2008), price instruments FITs and FITPs have generally performed better in reducing the cost of technology (significantly or moderately significantly) than quota obligation (with TGCs), competitive bidding, production and other fiscal incentives. Moreover, wind (both on-shore and off-shore) technologies exhibit the highest possibility of cost reduction, followed by combined biomass power and heat, with the lowest cost reduction experienced in case of solar PV. Notably, however, the cost reduction trends here have been reported only for the most dominant instrument used and not available for all the others. Furthermore, from the above sample, evidence is not clear as to whether FITs or FITPs are necessarily associated with mature markets for technologies in comparison with quota obligations or tendering schemes.

4.2.4 Impact on innovation

There is lack of conclusive evidence on the link between energy support measures and innovation (EEA, 2014). It depends critically on the original goal of the energy support measure: attaining social equity and access, achieving energy security, correcting for externalities, supplementing domestic production and spurring employment. The data for the EU-27 group of countries for the period 2005-2011 demonstrates a weak relationship between per capita renewable energy production of wind, solar and geothermal and per capita patent applications granted in these categories (Figure 7). Denmark is the only exception: it exhibits a much larger share of patents compared to the other countries. This is followed by Luxembourg, Norway and Switzerland which too display a relatively high number of patents compared to their renewable energy generation from these specific technologies. In comparison, Italy, Portugal, and Spain have much fewer patents applications as compared to their renewable energy generation. This leads to the conclusion that a mere strong focus on deployment (demand-pull) does not necessarily lead to accelerated innovation in the renewable sector.

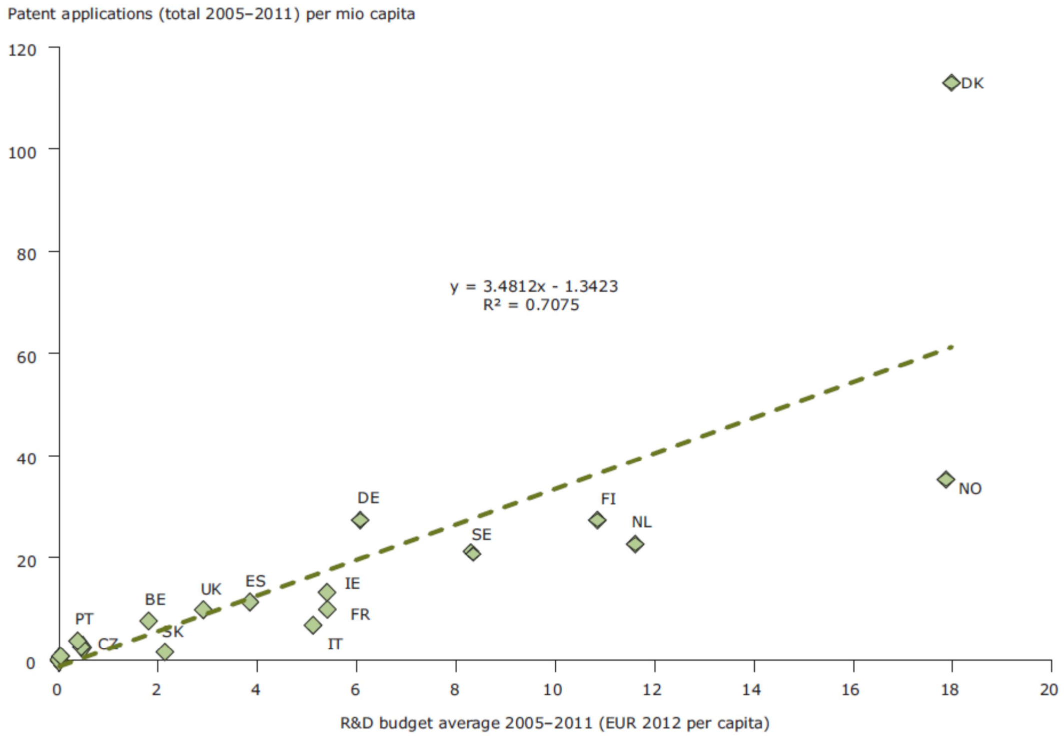
Figure 7: Patent application versus renewable energy production per capita in select countries



Note: These technologies were selected as relatively new renewables technologies, and production was calculated as an average over the period from 2005 to 2011. In addition, an analysis for the total renewable energy production would be heavily influenced by hydro electricity production, and would show less clear linkages with patent applications.
Country codes: AT (Austria), BE (Belgium), BG (Bulgaria), CH (Switzerland), CY (Cyprus), CZ (the Czech Republic), DE (Germany), DK (Denmark), EE (Estonia), ES (Spain), FI (Finland), FR (France), GR (Greece), HU (Hungary), IE (Ireland), IS (Iceland), IT (Italy), LI (Liechtenstein), LT (Lithuania), LU (Luxembourg), LV (Latvia), MT (Malta), NL (the Netherlands), NO (Norway, PL (Poland), PT (Portugal), RO (Romania), SE (Sweden), SI (Slovenia), SK (Slovakia), TR (Turkey), UK (the United Kingdom).
Source: EEA, 2014.

In contrast to the above findings, there is clear evidence that public support for R&D have proved to be an important driving factor for innovation. Figure 8 demonstrates that there exists a strong positive correlation between R&D expenditure and patents applications.

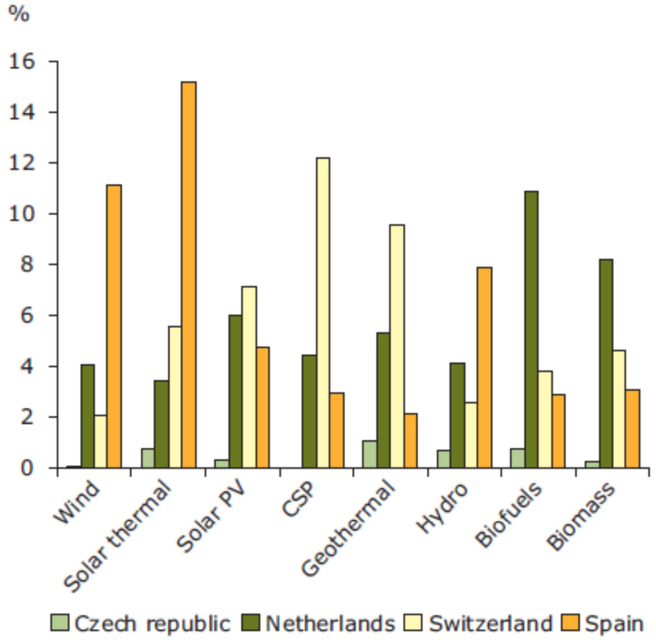
Figure 8: Patent applications per capita versus R&D budgets per capita in select countries



Note: For country codes, please see refer to note attached to Figure 7.
Source: EEA, 2014.

The detailed cases of four countries out of the EU-27 group, namely Czech Republic, Netherlands, Switzerland and Spain, are illustrative. For these four countries, the Figure 9 below depicts the data on share of renewable energy technology patent applications in the total patent applications in the EU-27 and Switzerland between 2006 and 2010 (the years covered here are different owing to limitations of data). AS can be seen, the data for Spain point to the fact that RE deployment had led to substantial R&D activity. Spain demonstrated a very high share in patent applications for wind, and a relatively high share for solar PV as well. There was a rapid increase in the number of patents for both these technologies between 2006 and 2010. In comparison, however, for concentrated solar power (CSP), Spain had a relatively low share in patent applications during this period, despite CSP being acknowledged as an important technology for the Spanish RE deployment. By contrast, Switzerland demonstrated the highest share in CSP and solar PV patent applications, despite very low deployment rates. The same holds true for Netherlands as well.

Figure 9: Share of RETs patent applications in the total patent applications of EU-27 and Switzerland between 2006 and 2010



Source: EEA, 2014.

In all the four countries the key driver for innovation in the RES sector has been the availability of targeted funding for R&D. In the Netherlands, for example, funding allocation can be ascribed to the specific demands of (mostly larger) private industry players that worked through innovation contracts. In addition, in the Netherlands the existence of a strong PV cluster in the south-east of the Netherlands (Limburg and Noord-Brabant), comprising producers, suppliers and equipment factories, has spurred successful R&D in solar PV. In comparison, Switzerland's strong point in solar technology could be linked to its existing technological capabilities in this area, while its forte in geothermal stems from its relatively high domestic potential for geothermal energy. Spain's leading position in wind and solar thermal may be related to its early mover status in these technologies. By comparison, in the Czech Republic, a number of sectors already exist where skilled labor force and innovation activities has helped shore up further innovation in the RES sector, such as electrical and electronics engineering, mechanical engineering, wood processing, and information and communication technologies. Further, environmental awareness has been high in the Czech Republic, leading to the setting up of technological parks and business incubators for eco-technologies.

4.3 Key lessons learnt

According to IEA (2008) and IEA (2011), some key points need to be borne in mind in the choice and design of support instruments for effective and efficient RE deployment. For example,

- FITs/FITPs have observably had their impact on RE deployment in varied situations. For FITs, support levels can be customized, and combined with regular built-in tariff reviews to avoid over-compensating investors as costs reduce over time. This is especially true for modular technologies with short development times and high learning rates (such as solar PV), for which built in mechanisms to avoid explosive growth (via a capacity or expenditure cap) becomes necessary. FITs do not expose the technologies to the direct competitive market with other technologies. They are, therefore, well suited to technologies that are some way from being competitive. Implementing a feed-in system in the form of a premium on top of electricity market prices can be used to expose technologies to competition.
- TGCs are also known for being effective at stimulating RE deployment. In this case, deployment volumes and prices can be regulated via caps, buy-out fees, and price floors and banding, which compensates different technologies with specific measures. These controls, however, still continue to risk over-rewarding some technologies. In general, given the overall nature of support, TGCs are best suited for the more mature technologies that are approaching competitiveness and as a market-based mechanism.
- Competitive bidding/ tenders offer high security for project investors once the bid has been won. In the initial phase of project development, however, tenders tend to carry a very high level of uncertainty for investors, which could pose a hindrance, in particular, for smaller developers. An advantage of this instrument is that it permits competitive price discovery and, therefore, provides an opportunity to bring forward quantified levels of deployment at a low cost in the context of the local market. It is considered best suited for mature technologies that are becoming close to being competitive.
- Grants provide a less complex instrument to stimulate RE deployment, but these are perhaps most appropriate for technologies at or just leaving the demonstration stage, and for deployments at a limited scale or overall capacity. Grant schemes are often constrained by budgetary changes, and thus fail to provide the long-term market certainty needed to develop an established supply chain capability.
- Tax incentives measures provide poor management of deployment volumes and prices, and wield little or no pressure on developers to control or reduce costs. They too are sensitive to budgetary constraints and may cause a stop-go deployment pattern not conducive to sustained growth in RE deployment.
- Evidently, high level of RE deployment encouraged by public support measures does not necessarily result in a sound and steady innovation process in a country. On the contrary, too effective (and too generous) policy support may not stimulate cost reduction via technological innovation, but rather culminate in high levels of deployment at high costs, as witnessed in the Czech Republic and Spain. Factors such as R&D budgets coupled with a strong national innovation policy and industrial base to support technology development and deployment are equally important for innovation in the renewable sector.

5. Country Case Studies

5.1 The case of FITs and emergence of PV bubbles in Germany and Spain

A number of countries that have relied on FITs/ FITPs as the dominant measure of support for RE deployment have witnessed larger than expected amounts of installation of solar PV capacities. These unexpectedly large and booming PV markets have posed a difficulty for policy makers and stakeholders, and have created both stress and lively debate around the cost of support policies. The debate has spilled across to other renewable support policies, although the problem is essentially confined to solar PV. The case of the PV boom in Germany and Spain is illustrative.

Germany has been supporting solar PV growth at the regional and national level since the early 1990s by relying on a range of policy mechanisms. Germany managed PV volumes for much of the last decade by utilizing pre-determined rate decreases. The most recent breakthrough in policy space has been the introduction of PV rates that decline based on the amount of capacity installed in the prior periods. That is, the price paid for PV per unit is now linked to the PV market volume. As observed by Fulton (2011), from an investor's perspective, time triggered automatic rate adjustments based on volumes, whose circulation formulae are transparent and methodically grounded best deliver the triple features of transparency, longevity and certainty (TLC). When combined with transparent, periodic reviews, such adjustments can render the flexibility deemed to support policy longevity. Thus, after relying on the hard caps for its PV FIT policies of 1990s and early 2000, the German government has since relied on strategies for limiting (enabling), market growth by regulating the FIT price levels. For instance, there was only a single rate available for PV technology during 2000-2003. Starting with 2004, Germany introduced PV rates that were differentiated by size (e.g. capacity) and by application (e.g. façade integrated or free standing).

Germany managed to consistently exert a downward pressure on solar PV prices through degression during the past decade. During 2000-09, degression was set as a fixed annual amount. During 2009-11, however, the German government introduced a volume response "corridor" or "flexible" degression schedules. During the same period, the government also implemented the concept of "non-scheduled adjustments" as a result of unforeseen developments in the prices of PV systems. It was observed that since 2008, PV component prices declined sharply, with panel prices falling around 40% in 2009 alone. These degressions and pricing mechanism adopted by the German government resulted in sharp decline in rates in 2009-10 in response to significant acceleration in market growth. Subsequently, the non-scheduled adjustments that took place in 2010 and 2011, in response to decline in the component costs, led to reduced market transparency. But these interventions were necessary to ensure long term policy durability.

Due to the well managed price degression followed by Germany, the scale of the PV industry, transaction costs- including grid connection fees and installation- were significantly lower compared to other European countries. Thus, the use of price to control volume rather than putting hard caps on volume was a strategy which really nailed the success s of FIT for PV in Germany.

Spain's FIT policy was kick-started with the Electricity Sector Law of 1997 (Law 54/1997) with the very first amendments ushered in 2004, when a target of 150 megawatts (MW) for solar PV were established. It was envisaged that once the targets are reached, the support levels would be adjusted. This policy change came under criticism from the RES generators, who argued that that the annually revised support levels were not transparent and raised the risk for investors, thus causing high risk premium being charged from them by the lending institutions. In 2007, post detailed negotiations with investors and developers; the Royal Decree 661/2007 was promulgated leading to a marked impact on Spain's solar PV sector, which delinked the FIT rate from the Average Electricity Tariff (AET). This is because as the AET rose between 2005 and

2006, the cost of RES-E support also rose, forcing the government to undertake system reforms. The other main features of RD 661/2007 in comparison with the past regulation were: revision of FIT rates scheduled for every four years, establishment of mandatory guarantees to prevent speculation, RE to receive priority access to the electricity grid, evolving a long term energy plan (2011-2020) and putting in place a cap-and-floor price system.

An immediate fall out of this policy change was a sudden massive spike in PV delivery in 2007 and 2008, due to the generous FIT. This was ruined as the government stepped in to reduce the costs of the FIT. This angered the investors and the failure on part of the government to control costs damaged the future prospects of taxpayer-funded solar PV delivery in Spain and lost the faith of the investors.

Initially, there was a steady but low rate of installation up until 2006, followed by a sudden massive spike in deployment in 2008, and later a reduction in support, led to a subsequent plummeting of installations to zero the following year. By 2009, the total annual cost of subsidizing solar PV was $2.6 billion per year. At this level of expenditure, solar PV subsidies represented over 50% of all RE spending, despite producing a mere 12% of all renewable electricity generation, and only 2.45% of total electricity generation.

The poor design of FIT was one of the main reasons for its failure in Spain that included:

- An over-generous rate structure of FIT, especially in 2007
- No subsidy degression initiation with the falling cots of the solar PV projects.
- Extremely long period of transition to policy schemes when tariff reduction was expected.
- A lag in the reporting of investments by regional government.

The government basically failed to lower the compensation in response to the rapidly declining costs on account of technical change and learning. It failed to take into account the external factors as well. The problem was that investors were able to install the solar PV, which is a modular technology, in a short time span while the policy makers were not able to react to the changing conditions at the same rate. This led to slower internal communication within the government machinery, making the national government aware of the scale of regional investments with a significant delay, when the crisis had already hit.

The final outcome was a lose-lose situation for all stakeholders. The electricity system was burdened with costly solar PV generation. The policy changes had repercussions for the ongoing viability of the industry, with solar PV developers losing faith in the government's retroactive tariff changes. Numerous companies associated with solar PV manufacture either had to close down or undergo a merger, and employment in the sector fell from a high of 41,700 reported jobs to fewer than 10,000 in 2012. In fact, the recurrent policy changes had far reaching implications for RE sector as a whole, damaging the investor confidence in the reliability of Spanish policy framework. The performance of regulators and policy-makers was heavily criticized by industry associations, solar PV investors, generators and environmental NGOs.

Table 9: Experience with FITs in Germany and Spain: A Comparison

What Germany did	What Spain did
Used price to control volume (**no hard caps**)	**Overcompensated** solar PV
Increase in solar PV delivery with a **fall in FIT costs**	**Exponential** growth in solar PV deployment with a corresponding **growth in costs of FIT**
FIT degression options- Degression was automatic and transparent	**No subsidy degression** options- transition period between revisions of FITs were too long
Initially a fixed degression followed by a flexible degression schedule	Rise in prices of Solar PV subsidies
Active policy makers and **political consensus** in tune with investor's needs	**Slow reaction** by the government in turn hurting investor confidence
Adopted **triggers, adjustments** and most important **review** concepts and how it impacts TLC	Should design a policy that **avoids cost crisis**, develop tracking methods so that government can **detect and react** to problems promptly and try to **limit damage** in case of crisis
Increased employment and trade in international market of solar PV	Domestic **job losses** and contraction in international market
Merit Order Effect (MOE) took place	No MOE took place
Germany is world's dominant solar energy market	The solar energy market failed in Spain

Source: Authors

5.2 The experience with auctions in Brazil

Electricity auctions have occupied centre-stage in the regulatory framework adopted by Brazil when it embarked upon the reforming of its electricity sector in 2004. Since then, regular operation of energy auctions have resulted in the construction of 58 GW of new generation capacity (of which 46% is hydropower and another 29% is from other RE sources), through about $350 billion in long-term contracts. Through a review of the Brazilian long-standing experience with auctions, several strengths and weaknesses of the measure come to light. Wind energy auctions have, in particular, progressed in two phases. The first stage was marked by a strong policy determination to promote the development of nonconventional RE sources, in the post 2012 period, in order to diversify the primary energy supply mix in favor of small hydro, wind, and biomass energy. In this stage, contracts were especially structured incorporate the features of individual technologies, so that more investment could be attracted by offering an instrument that would insulate the investors from risks—such as inflation and the uncertainty of variable generation. Consequently, the result was a humungous success with RE auction managing to attract large amounts of investments from both the public and private sectors and allowing consumers to benefit from cleaner energy at cheaper costs. The huge success brought along with it some criticism associated with the fact that the terms offered in contracts were too generous for investors and that, as a result, generators had an incentive to bid aggressively and to make impractical promises about their plants' anticipated performance. With security of supply in mind, the second stage of wind power development with auctions was ushered in 2013 with much needed revisions of some key aspects of the auction design now seeking an optimal allocation of risk in the contracts offered to wind producers.

So far, Brazil has adopted two types of auctions schemes for deployment of RE: technology-specific auctions and reserve energy auctions. Technology-specific or project-specific auctions are used to deploy new capacity and supply the regulated market, when the auction has been targeted to support specific energy policy decisions or the introduction of special projects (such as large hydroelectric plants). In this case, contracts have to procure Firm Energy Certificates (FECs) to ensure that new power production is added to maintain minimum adequacy and reliability levels at the system level. Reserve energy auctions, by contrast, are carried out to directly increase the system's reserve margin. In this case, contracts need not be covered by FECs, and the auctioned quantity is independent of the demand forecasts issued by Discos.

Several points are noteworthy about the Brazilian experience with auctions for RE. The performance of RE procurement through reserve auctions has been relatively better than through technology-specific auction. The lackluster performance of the latter can be attributed to: ability of RE developers to obtain obtained higher prices in the free market on account of the attractiveness of the T&D discount, general difficulty for RE to comply with FEC coverage obligation, since intermittent generation tends to face the risk of penalization, finally, the upper limit for the remuneration level in the auction was set at a rate lower than that allowable on an under the PROINFA (the early policy framework on RE promotion). In comparison, the reserve auctions have emerged as a more promising option, as these are beset with lower risks for the investor. As of today, three rounds of reserve energy auctions for RE have been initiated (August 2008, December 2009, and August 2010), providing a total capacity of about 6.2 GW in small hydro power, sugarcane bagasse cogeneration, and wind-based generation for delivery during 2008 and 2015, and with contract terms ranging from 15 to 30 years (Azuela and Barroso, 2011).

Secondly, auctions have resulted in huge price reductions, largely on account of competition between national and international companies. For instance, as compared to the PROINFA period, prices fell by nearly 45% in the 2009 auction alone, and then they fell by almost a further 40% in 2009-2011. Due to these significant price reductions, wind farms' participation in the regular new energy auctions over the past few years has contributed to bring down the price of new generation in Brazil as a whole. From the history of all the auctions for new capacity that have been carried out in Brazil since the 2004 market reform it can be inferred that, between 2005 and 2009, auctioned prices that had been stable at around 80 US$/MWh, after 2011 stabilized around a lower value of 50 US$/MWh. Thus, Brazilian wind energy auctions contributed to enhanced competition in conventional energy auctions, driving down investors' profits and allowing consumers to capture the benefits of lower energy prices (Azuela et. al, 2014). Concomitantly, this has raised the concerns as to the extent to which auction winners will be able to construct and profit from the plants.

Thirdly, concerns have been raised with regards to impact of competitiveness of the bids on the sustainability of the Brazilian wind auction mechanism in the future. Given the regular financing conditions and given investment and operation costs, bids in the most recent auctions have been below the level that could sustain the wind power supply chain, thus compounding the risk of construction delays or defaults by the winners that placed unrealistic or adventurous bids. This apprehension has been enhanced by the fact that the auction's ceiling prices have posed constraining parameter for the investors' remuneration rise.

Fourthly, another phenomena associated with the wind energy based auctions is Brazil is that these have prompted the participation of new equipment suppliers to the wind energy market. In addition to Wobben Wind Power, which has been present in the market for many years (a subsidiary of German company Enercon), IMPSA (Argentinean), Suzlon (Indian), Vestas

(Danish), Siemens (German), and GE (United States) are now operating -- or in the process of commencing operations—in Brazil (Azuela and Barroso, 2011).

Lastly, and most recently, the Brazilian government's strategy of adopting tight ceiling prices seems opposed to the country's past experience, since in the earlier auctions competition among suppliers was the most important factor that led to price reductions below the ceiling. Recently, especially for the regular new energy auctions, this strategy has brought in a risk of compromising security of supply if auctioned demand is not met. In fact, the observable trend of having a marginal price so close to the ceiling price in the recent auctions points toward the fact that there has been hardly any competition encountered, with many suppliers dropping out immediately and others simply offering the ceiling price.

In general, auctions appear as an effective market-based instrument for stimulating competition among investors, providing price disclosure while eliciting the optimal amount of investment, and offer revenue stability via long-term contracting. The key lessons learnt from the Brazilian experience are (Azuela et. al., 2014):

- Auctions tend to make available stable guarantees to both investors and consumers. Auction winners are assured a steady, long-term revenue stream, while consumers benefit from the security that the optimal amount of renewable energy capacity will be installed.
- Well-conceived auction schemes could spur a country's renewable energy program. By attracting attention from national and international players, well-organized auctions provide an interesting alternative for countries in which the energy market lacks a mature RE segment. In fact, this is why auctions have been popular in emerging economies, such as India and Brazil, where the risk of a few firms exerting too much market power has been a barrier to RPS schemes.
- To allow policy consistency and compatibility, auction mechanisms should be fully integrated with other regulatory, planning, and economic strategies of the country.
- Evidently, auction mechanisms have proved to be very effective in lowering energy prices in Brazil, China, and India, when compared with the levelized cost benchmarks calculated on the basis of "reasonable" assumptions (which are generally used to ascertain an auction's ceiling price and price levels for FIT programs).
- Discouraging overoptimistic behavior has been a major challenge of past implementation of auctions. Commonly, delays in construction and underperformance have been identified as key systemic problems with auctions. Although these problems can be dealt with to some extent by stiffening penalties for failing to meet the original objectives, it does seem that more often than not, winning the bid represents a best-case scenario rather than a most probable one. Policy makers should be aware of this risk seek to build mechanisms that would provide early warning of potential problems, so that mitigation measures can be taken at the earliest possible stage.

5.3 United States' Production Tax Credit Program (PTC)

United States (US) has one of the largest PTC program. A PTC aims at incentivizing renewable energy production and provides tax benefit against the amount of renewable energy actually produced and fed into the grid. According to the American Wind Energy Association, this performance-based incentive has helped the US wind industry lead the clean energy market. It rewards producer on the basis of actual energy produced, increases the rate of return to the investor and reduces the payback period as well. PTC has often been preferred over investment incentives because the latter cannot promise installation at optimal level whereas production incentives encourage optimality as well as sustainability in the industry (Sawin, 2003).

The need for a secure, supply of homegrown energy source to power the nation led to introduction of PTC in US. PTC was first implemented in US as part of the Energy Policy Act of 1992 and, in combination with the renewable electricity standards, has been the main driver of wind power development in US since then. PTC covered wind and bio energy resources. The PTC provides a 2.2% per kilowatt hour benefit for the first 10 years of a renewable energy facility's operation. In order to avail this, the wind energy equipment should be located in US and energy produced should be sold to an unrelated party only. The unused credits can be carried forward for up to 20 years following generation[18]. PTC has contributed significantly towards wind power development and research and development in the sector. Installation of wind capacity at large scale in Texas along with introduction of US Federal PTC has made wind energy competitive. The US department of Energy quotes that US wind capacity has more than tripled during 2007-12 and the costs of generating electricity from wind have fallen during this period. But lapses in the policy have led to a dramatic slowdown in the planned wind projects which affects the further growth of industry. While short term PTCs are less likely to induce adequate R&D, long term policy of PTC can spur positive growth in R&D and innovation. Short term PTCs expiring soon lead to hurried investments with small installation capacities and thus high electricity costs.

The main issue with the U.S. PTC for wind energy has been that it was allowed to expire several times and was extended some time later and this has led to cycles of boom and bust in the market which in turn has led to suspension of projects, worker lay-offs, and loss of momentum in the industry. This approach of halting and then restarting of policy has posed challenge for the US industries (Sawin, 2003). Long term extension of PTC will help development of renewable energy capacity by bringing stability in the wind energy sector. This will bring wind energy at par with fossil fuel and nuclear power industries which have enjoyed incentives for long periods[19].

The American Wind Energy Association reports that PTC fosters economic security as the price of wind power has dropped by around 43% over the past four years (2008-2012) benefitting the consumers as well as utilities (AWEA, 2013). According to the US Dept. of Energy (2013), there are over 550 US wind equipment manufacturing facilities across 43 states and for the past five years, this industry has been driving $15 billion of private investment on annually.

In 2012, the threat of policy expiration halted wind development. In 2013, tax credit extension restarted project development and spurred job creation in the wind industry. For the biodiesel industry as well reinstating these incentives after 2011 has provided certainty to growth in the industry.

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[18] Renewable Electricity Production Tax credit, Database of State Incentives for Renewables and Efficiency, DSIRE, North Carolina State University, 2011

[19] Union of Concerned Scientists (Based on data from US Dept. of Energy and American Wind Energy Association)

The lesson learnt from the US experience in respect of this policy incentive is that frequent expiration of the policy created uncertainty in the industry which posed a challenge to development of renewable energy and this could be corrected by appropriately timing the extension of PTCs which can cater to the issue and provide for continued expansion and economies of scale to persist.

5.4 Canadian experience with RETs

It was only after the signing of the Kyoto Protocol in 1997 that effective support policy for RE was introduced in Canada (Jager and Rathmann, 2008). In Canada, hydropower dominates the renewable electricity mix and production of RES-E has followed an upward trend. For total biomass production, based mainly on capacity installed prior to 2000, Canada is among the leading countries. Bio energy has dominated the average annual renewables RD&D budgets during the period 1990-2006, followed by solar PV (IEA, 2008).

Canada employed three policies to reduce financing costs to support RES-E: low interest loans for project development by municipal utilities, accelerated depreciation to improve overall cost effectiveness of RES-E projects, and investment subsidies for electric retailers that produce RES-E (Jager and Rathmann, 2008). It also introduced tender auctions to secure long-term contracts and to maintain investment certainty and minimize policy costs. Capacity payments were used as a policy tool to encourage positive interplay of RES-E with markets, which could be adapted to suit all types of available capacity. Feed-in-tariffs have been another incentive introduced in 2006 for wind, biomass and hydro projects. Feed-in-tariffs and tendering schemes contributed most significantly towards reducing the cost of RES in wind onshore projects in Ontario and Quebec whereas production incentives' contribution to cost reduction proved to be insignificant (Jager and Rathmann, 2008). The net metering scheme in Canada allowed producers to receive credit only to the point where production equaled their consumption and this benefitted the providers and system owners (especially in case of solar PV), as the excess power generated during peak time could improve system load factors and avoid the need for new systems (Sawin, 2003). Canada is among one of the highly deregulated jurisdictions which has been considering liberalizing market structures in order to better coordinate planning for low carbon systems dispelling the myth that only regulated environment can help switch towards low carbon systems (Miller et. al., 2013).

The Eco-energy for Renewable Power Program was launched in Canada in 2007 to provide incentive of 1% per kWh, for up to 10 years to eligible projects constructed over next four years that can generate clean electricity using renewable sources. The program will end in 2021. Wind, small hydro, biomass, solar PV, geothermal, tidal and wave technologies have been the eligible sources. Tax incentives have been provided for business investments in energy conservation and renewable energy with no restrictions on the size and type of applications for solar air and water heating systems. Canada provides production incentive for wind generated green power on the basis of each kWh of power generated. Support policies to encourage use of green fuels like ethanol and biodiesel have also been introduced by Canada. It has introduced an Environment Choice Program which provides for EcoLogo certification for automotive fuels that produce lower emissions. However, efforts are required by Canada to remove barriers that limit investments in renewable energy on account of lack of sufficient information, inadequate regulatory structures, and instability of incentive programs (Pembina Institute, 2013).

Canada has remained a steady investor in renewable energy in the recent years, mainly for large scale wind and solar PV projects in Ontario (Global Status Report, 2014). The wind-diesel hydrogen project in Canada (Island of Ramea) is an example of a project with appropriate institutional framework, innovative power purchase agreements, and targeted support from different levels of government and such factors can help in attracting investment. Adequate and transparent information dissemination plus community involvement in renewable energy projects for supplying electricity to remote areas have been successful in managing and operating systems by the Electricity Sector Council in Canada (IEA, RETD, 2012).

There is a comprehensive renewable fuel strategy of the Government of Canada which mandates minimum level of renewable fuel content at 5% for gasoline pool and 2% for diesel and heating oil. It provides support for farmer participation in industry through an eco-agricultural bio fuel capital initiative, support for next generation technologies for bio fuel generation and domestic production through an operative incentive system (Government of Canada). According to a report by Canadian Renewable Energy Alliance (CanREA 2006), investment in renewable energy technologies is lagging behind because a lot of investment is still being made to promote conventional sources of energy such as fossil fuels, large hydro and nuclear energy. Even in Canada, there is a rise in subsidies to Canadian oil and gas industry which might be crowding out investments in renewable energy technologies. Canada lags behind countries like US, UK, China and India in support towards RETs. The following recommendations are made by CanREA (2006) in this regard:

- Policies and strategies to be put in place by provincial governments that maximize private, community and public investment in renewable energy.
- These to be achieved through incentive mechanisms like RPS, FITs, green certificates.
- Diverting investment flows from conventional sources of energy to renewable sources.
- Removing barriers to installation and development of such sources technically (like existence of building codes).
- The federal government to play a leading role in establishing a national renewable energy and energy efficiency investment facility and introduce innovative financing like micro credit.
- Setting up of Canadian venture capital funds and debt financing facilities to promote RETs.

5.5 Denmark: The case of a leader in innovation in RETs

The patent activity is a significant measure of a country’s level of specialization in certain technologies and of future potential for market share growth. From the analysis presented in Section, it is evident that Denmark is a clear leader as far as the number of patents filed in RETs as compared to other countries.

Denmark (besides Germany and Japan) can be termed an established RE market leader that has long placed its industrial and economic development objectives at the heart of its support for RETs (IEA, 2011; Jochem et al., 2008; Mizuno, 2010). Denmark has promoted the creation of effective industrial clusters and developed vibrant home markets by instituting stable, enabling policy frameworks along the innovation chain, besides creating favorable investment conditions for innovative RE technologies, including solar PV and wind. It has specialized at an early stage in the supply of new RE technologies that were embodied with high knowledge intensity and learning potential, and thus the country has emerged a front-runner in terms of RE innovation (IEA, 2011).

Recently, on 22 March 2012, Denmark witnessed the signing of a political agreement amongst the major political parties, which set the institutional structure for a changeover to a green and sustainable energy economy in the country. One of the provisions of the framework was large investments in RE and energy efficiency up to the year 2020 (in the range of DKK 90 million to DKK 150 billion). In addition, the energy agreement also set the stage for need for a continued intensive research, development and demonstration of new green energy technologies. However, this is not a new development. Denmark has been consistent in implementing sustainable energy concepts over the years, and it is now very advanced in achieving a sustainable energy system through increased energy efficiency and the share of renewable energy as well as the integration of energy networks (electricity and heat but gas as well is being considered) Furthermore, Denmark has had a very favorable environment for innovative clean-technology start-ups (EEA, 2014).

A closer look at patent applications in Denmark shows that most of the patents are in wind energy technologies. Wind power made available over 30% of electricity production in Denmark in 2012, and this is expected to rise to around 50% by 2020. Moreover, historically, Denmark has been a pioneer in developing commercial wind power during the 1970s, and today a substantial share of the wind turbines around the world are produced by Danish manufacturers such as Vestas and Siemens Wind Power along with many component suppliers (EEA, 2014).

The key lesson to be learnt from Denmark is that its current position as a front-runner in innovation in RE can be ascribed to the bold political decisions to transform the energy system, the early mover advantage in wind energy, and a favorable climate for innovative start-ups. The relatively low costs of patent applications and the opportunity to apply for patents in English language may have also played a conducive role in this regard (EEA, 2014).

5.6 FIT experience in Indonesia

Renewable energy plays a very small role in the Indonesian national energy supply, accounting for only around 6 per cent of the total final energy supply. Most renewable energy comes from geothermal, hydro and biomass power. The country's geothermal resource is estimated at around 28 giga watts (GW) of capacity, about 40 per cent of the world's known potential. At the moment, the installed capacity is less than 1.2 GW, only around 2.7 per cent of Indonesia's total installed power capacity in 2011 (Warnika, 2012). Several independent power producers (IPPs) operate geothermal power plants in addition to the plants operated by PLN. While the cost of geothermal is low, high upfront capital requirements have hindered development.

Hydropower is also estimated to have the potential to reach 75 GW. Currently, only 7 per cent of this has been developed, mostly by PLN, but with some plants operated by private power companies (Warnika, 2012).

Indonesian Presidential Decree 26/2006 set a target for RE at 17 per cent of the total energy mix by 2025 which was revised in 2010 by the Ministry of Energy to up to 25 per cent. Several policies have since been introduced to support RE development. The most recent is a new regulation setting out a feed-in tariff for renewable electricity. This requires the National Electric Company (PLN) to purchase renewable electric power at pre-decided prices (Table 10).

Another support measure apart from Feed-in Tariff available to RE is a guarantee for PLN's business viability for power projects operated by IPPs for energy technologies specified under PLN Fast Track II program. It is available to all renewable energy technologies, but since the program covers only large projects, geothermal and hydro projects get the benefit.

Feed-in Tariffs

The feed-in tariff is set by the government at the start of the project with an assurance that PLN will take all the electricity produced by the power plant in question. This price certainty reduces the risk associated with recovering investment and operational costs. A guarantee of this kind is particularly important in Indonesia, where the PLN's domination of transmission and distribution makes the electricity market a monopsony (buyers' monopoly).

As of 2012, the government of Indonesia has introduced FiTs for the purchase of electric power generated from various renewable sources (Table 10). To encourage use of RE by smaller-scale power plants, the government has introduced FiTs for mini and micro hydro power, biomass and waste power plants. The FiTs vary across technologies, location and whether it is connected to a low/medium voltage network. Connecting to a medium voltage network fetches a lower tariff rate (Rp 656 /kWh) than connecting to a low voltage network (Rp 1004 /kWh). This can be problematic since interconnection with a low-voltage network tend to be unstable if there is a high-voltage fluctuation, which may adversely impact the performance of power plants. Other measures to promote the use of solar power, including feed-in tariff and purchasing arrangement for small scale users, are currently under consideration ("Tarif Listrik Tenaga," 2012).

Table 10: Feed-in Tariffs in Indonesia from different energy sources

Energy Source	Feed-In Tariff	Conditions
Geothermal	U.S. cent 10–18.5/ kWh	Depends on location, and whether the power plant is connected to a high- or medium-voltage network.
Mini and Micro Hydro	Rp 656–1,506/kWh	<10 MW; depends on location and whether it is connected to a low/ medium-voltage network.
Biomass	Rp 975–1,722.5/kWh	<10 MW; depends on location and whether it is connected to a low/ medium-voltage network
City Waste	Rp 850–1,398/kWh	<10 MW; depends on the technology utilized and whether it is connected to a low/ medium-voltage network

Indonesia has also introduced 'bidding mechanism' which facilitates awarding construction rights and higher tariffs to specific developers. While there has been progress due to these incentives, problems have also been experienced due to the co-existence of bidding mechanism and feed-in-tariffs. The government had to annul the outcome of some bidding processes for geothermal projects because the winning bids demanded a power tariff higher than the rate set by the government's feed-in tariff. In all these cases the bidding was conducted by the local governments[20] where the project will be located. This is attributed to lack of technical capacity and/ or conflict of interest may exist—local governments have an incentive to allow bidders to set higher feed-in tariffs, as they receive royalties from renewable power projects operating in their jurisdiction.

Key Lessons

- Lack of coordination and conflict of interest between different tiers of government institutions can adversely impact the pace of RE development.
- Technical issues based on interconnection with grid may need to be given due diligence before arriving at the tariff rates based on the scale of the renewable energy plant.

6. Issues in how to allow built-in flexibility level and timing of slowing/tapering and an exit point/policy

These are particularly tricky questions and would require a case by case examination, analysis and solutions. Though country experiences can provide useful information interesting insights from some of the evolving literature on evaluating the impact of different emission mitigation measures and using feedback loops in phasing out of CFPI can be very useful.

The bottom-up energy system models with their high level of technological detail allow assessing the effects of technology-specific measures and technological breakthroughs in ambitious emission reduction scenarios. A limitation of conventional bottom-up models, in particular, with respect to the inclusion of macroeconomic feedbacks has led to development of hybrid model approaches. However, these new techniques only offer an added value if the additional parameters are based on a good empirical foundation (Götz et al., 2012). An interdisciplinary research approach with inputs from disciplines like behavioral economics, social psychology is required.

There are some strong arguments in the literature for invoking technological advancement policies as additional public policy measures and these have received support in success stories of implementation of instruments such as Feed-in-Tariffs or Renewable Portfolio Standards. The qualitative and quantitative indicators are being developed to inform the choice and design of appropriate instruments. Yet challenges in understanding (leave aside comparing) the impact of technology instruments and gaps in empirical research pose challenges in choice of appropriate instrument(s) as well as in design of specific instruments. The main questions are: at what cost and for how long? This is partly due to the fact that the efficacy of some of these instruments is beginning to emerge especially in emerging economies.

A key consideration in this context from an efficiency and cost effectiveness perspective would be to give an operational perspective to the choice and design of instruments by evolving a

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[20] Since the decentralization process began in Indonesia in 2001, some authority over investment procedures and related government revenue has been transferred to regional and local governments. Regional governments, for instance, have the right to determine the site of business activities following their local development master plan. Often, investors that have secured permissions from the central government will need to reevaluate their plans in order to comply with regional and local governments' requirements, or even totally cancel them (Pambudhi, 2006). Local governments' may also hinder or promote investment decisions through regional fiscal policies, such as local taxes and levies or local subsidies.

framework for optimal plan for offering and then phasing out these incentives/measures. This, among other things, would include: understanding of market dynamics, interactions among policy instruments, understanding of entry points both in scale and magnitude, a slowing/course correction strategy (by incorporating feedback loops, learning by doing, information diffusion), an exit strategy as market dynamics change.

Lobel and Perakis (2011) modeling the adoption of solar photovoltaic technology as a diffusion process (where customers are assumed to be rational agents following a discrete choice model) show how this framework can be used by policy makers to design optimal incentives to achieve a desired adoption target with minimum cost for the system. In particular, this policy design model takes into consideration network externalities such as information spread and cost improvements through LBD. The paper shows that the current solar policies in Germany are not efficient. More subsidies should have been required in the beginning — a stronger subsidy policy, perhaps — and a stronger phase-out in the later stages of the program. The reasoning is that in the early stages of the adoption process, it is optimal for the government to provide strong subsidies, which take advantage of network externalities to reach the target adoption level at a lower cost. As the adoption level increases, these network externalities become saturated and the price paid for raising the adoption target becomes increasingly more expensive[21].

6.1 Important empirical questions around inherent flexibility and time-frame of support

Poor formulation and execution of public intervention policies might lead to overcompensation and excessive demand for new renewable installations. In the renewable energy sector, it is critical to have continuous reform of incentives schemes in light of the falling costs and progress along the learning of the technology. This is why it is suggested that the design of the support scheme should have the built flexibility in level and time frame to accommodate changes in the development of costs and technologies and minimize the financial support to be provided. A suitably designed phase-out plan for the support scheme would alleviate the need for authorities making ad hoc administrative revisions of the existing scheme in terms of its scope, level and the time frame (EC, 2013)

Specifically, as the renewable technologies evolve, markets mature and the costs of renewable energy lowers, the financial support to renewables will have to be gradually phased out, with the exception of the support for R&D expenditure to immature new technologies on the anvil with good long-term potential. Thus, the overall framework conditions which constitute the best-practices with regard to cost components and its calculation, automatic tariff degression and time frame for support are discussed below (European Commission, 2013) (Table D.1 in Annexure D provides a tabulation of the discussion in this section).

For competitive allocation schemes, *cost calculations* can serve as a reference for the policy makers or as benchmark for technology-staggered auction processes. Typically, cost calculations comprise three distinctive steps: (i) selection of cost parameters (capital and operating costs, fuel costs, network and grid connection costs, costs of market integration and such like) and a cost calculation methodology, (ii) setting the cost and revenue projections, and (iii) translating the levelized cost of electricity into an actual support level.

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[21] The qualifier is that due to limited access to data this is not a full empirical study of the German solar market. We have very limited access to data.

Incentive/ support schemes have to remain flexible enough to adjust as technologies evolve on the global market, mainly due to learning curves and technological innovation that lead to costs reductions. Consequently, it is suggested that schemes should include *automatic tariff digressive characteristics***,** as also built-in revision mechanisms.

For most renewable technologies characterized by medium to long time period for maturity, the *time frames for support* broadly vary between ten years to over twenty years, with most offering support for between eleven and fifteen years. Generally, shorter support periods entail a lower risk of regulatory change. In comparison, the longer the time frame, the greater will be the need for flexible, market-adapting schemes, to avoid frequent regulatory adjustments. An alternative to formulating time bounds in terms of years is to limit support in terms of "number of full-load hours supported". This approach comprises converting the number of years to be used as the time limit into a fixed amount of cumulative production to be supported, by relying on a reasonable assumption about the average/ typical capacity utilization factor.

In light of these considerations, the following discussion highlights the specific features that the individual support instrument must incorporate in its design to address concerns of flexibility of level and time phasing of the scheme (EC, 2013).

6.2 ***Best practices and experience with specific instruments***

6.2.1 *Feed-in-premiums*

Feed-in-premiums are a more evolved variant of feed-in-tariffs in that these offer varying degrees of market exposure for the producers of renewable based power. Feed-in-premiums are preferred over feed-in-tariffs for technologies that are approaching maturity. A well-defined premium helps achieve lower costs and spurs innovation by rendering support that is based on competitive allocation or by relying on a built-in automatic and predictable adjustment of cost calculations, providing investors with clear market signals.

A feed-in-premium’s effectiveness in terms of market exposure is contingent on it being fixed or variable, and in the latter situation, how is it adjusted (hourly, monthly and yearly) and whether a cap or a floor is prescribed.

A variable or a floating premium will automatically fall as electricity prices (and carbon prices) rise over time. A premium must be subject to some limits. A floating premium can attain effective system management and avoid over-compensation if it is set at zero for production during those hours when the system price is zero or when it is above the level of average remuneration deemed necessary.

A fixed premium ignores electricity price movements that culminate in over-compensation if prices are higher than the forecast (when setting the premium) or in losses, if prices are lower.

6.2.2 Feed-in-tariffs

Observably, the several changes in support in the recent years point to switch from *feed-in-tariff* to feed-in-premium schemes. On the positive side, feed-in-tariffs help insulate new market entrants from price risk from the market, thus lowering their cost of capital and encouraging private investment. Feed-in-tariffs are also amongst the simpler of schemes in terms of their execution, making them eminently appropriate for markets with a large number of less commercial participants (e.g. households or local community run projects).

On the negative side, feed-in-tariffs tend to exclude producers from actively participating in the market and hamper efforts to develop flexible and liquid electricity markets as the share of renewables grows. These also constrain the growth of certain technologies and pose the difficulty of setting appropriate tariff levels and in adjusting such tariffs. A way out of this is to plan in advance the adjustment in the support, so that these reflect the changes in underlying costs. For instance, existing tariffs may be constant for the full period or variable/ declining in case the capital costs reduce over time. The design of tariffs for new installations should also have the inherent adaptability to lower production costs. Interestingly, a third form of tariff flexibility set up in some recent schemes assumes the form of a volume induced deviation in the tariff support: if the costs of new installations reduce faster than anticipated and the growth in renewable installations grows beyond what was predicted, a volume ceiling would trigger a reduction in the tariff.

6.2.3 Renewable portfolio standards (RPSs)

RPSs are quantity obligations that require energy suppliers to purchase a quota of renewable, often associated with a green certification. Quota obligations lead to establishment of a market between renewables producers and suppliers of energy who can transact in energy or green certificates at a price ascertained by them and other market players. To avoid over-compensation, technology banding has been recommended. RPSs can be created with technology banding, where there is a wish to develop and deploy a variety of technologies, with differing costs. Technology banding helps prevent over-compensating cheaper technologies that enter the market at high prices set by more expensive technologies.

6.2.4 Competitive bidding

Competitive tendering or auctions can achieve significant competition amongst bids, thus leading to revelation of true costs of individual projects, permitting cost-efficient support levels to be determined. Generally, auctions require ex-ante calculation of the energy costs by the regulatory agency, and often prescribe a floor and ceiling prices.

With reliance on the market mechanism, auctions are a self-regulating instrument, with an inherent subsidy phase out mechanism. This is because a competitive bidding process, with clear and definitive rules, will reward low cost technologies and eventually approach zero, as the technology costs reduces and levels out to reach the grid parity level. There is empirical evidence to support this trend in case of well-resourced wind and solar power projects.

Table D.2 in Annexure D compiles the information on best practices in the design of the above instruments, with special reference to in-built flexibility and timing/ phasing-out aspects of the incentive/ support measure.

7. Conclusions

The issue of design and implementation of support measures for RE technologies is complex and require a nuanced, case by case approach. However, some broad conclusions can be drawn from a review of design and implementation of such measures discussed in the foregoing sections.

Foremost, the design of the support instrument needs to be placed in a specific policy context (e.g. energy and climate policies), with clear identification of drivers and barriers to its design and deployment. The role of the regulatory, institutional and political environment needs to be emphasized, especially as the level and structure of the instrument will have to be benchmarked against the prices of conventional energy, besides other advantages that conventional energy sources enjoy (e.g. supporting infrastructure, consumer acceptability, established technology and such like). The cost of renewable energy, as much as the grid based prices (and more recently the presence of carbon taxes) has a bearing of the viability of RE technologies. There is widespread recognition of availability of and connectivity to grid infrastructure as a constraint to diffusion of solar and wind power across a range of country studies.

Political will and incorporation of RE targets in the national policy framework are important to introduce and effectively implement policies on RET dissemination. China with its strong manufacturing base and aggressive incentive mechanism has clearly emerged as a world leader. Time bound objectives along with complementary policies towards diversification have been the mainstay of policy in China. In Germany as well, policies concerning RETs have been an integral part of the industrial development policy. Complying with international environment treaties helped Canada establish markets for RES-E. For India, both political resolve and need to comply with international treaties were the driving force. The French FITs suffered because of complicated administrative and planning procedures.

Policy support measures have been affecting the cost effectiveness of technologies by giving stimulus to RES. A significant impact on innovation could not be found for a large set of countries. The exception being the case of Denmark, in which a large number of patents were filed in accordance with the policy support. Government R&D support, however, has had a very significant and positive impact on the innovation in RETs. Germany, Spain, US (especially California and Minnesota) has had fully mature markets, which could be ascribed to the support schemes in RES-E sector that have helped in significant cost reductions.

In general, it has been found that price- based instruments have worked better as compared to quantity-based instruments, and amongst various RES, wind technology has had the maximum potential for cost reduction and dissemination. It is also commonly suggested that incentives/ support measures need to rely, as much as possible, on market based instruments, e.g. quota obligations coupled with tendering and/ or green certificates, such that the true costs get revealed. A caveat that is put forward in this regard is that reliance on market forces will circumscribe the ability of the producers to reap the sufficient rent that can otherwise help spur innovation. Thus, incentives for dynamic efficiency for less mature technologies (in particular) should not be ignored.

None of the instruments offer an optimal solution in all evaluation criteria. As a consequence, a government will have to select an instrument and sustain it in the long run in accordance with the relative importance of its objectives.

In a complementary way, conditions of a successful instrument vis-à-vis the regulatory risk include long-term government's commitment, foreseeability of the instrument and ex ante flexibility to capture decreasing RE cost and correct redistributive effects. The level of the support must not be abstracted from the incurring risks and transaction cost.

Cost of renewable energy technologies tend to fall as there is learning-by-doing and market maturation. Thus, the instrument design needs to have in-built flexibility in the price or quantity domain so as to adapt to the changing market situation. In this regard, a smooth phasing out/ exit policy for the RE technology is also prescribed as the levelized cost of the technology is lowered to approach that of conventional energy in the limit. With respect to the best practices for specific instruments, feed-in-premiums help in achieving low costs and innovation. FITs help in insulating the new market entrants by reducing the cost of capital thereby encouraging investment. Competitive bidding, being a self-regulating instrument has a built-in phasing out mechanism. It can be concluded that an instrument is appropriate when it is able to adjust flexibly according to technology learning, and has built-in revision mechanisms with respect to the global market scenario. A suitably designed phase-out plan for the support scheme would alleviate the need for authorities making ad hoc administrative revisions of the existing scheme in terms of its scope, level and the time frame and avoid undue burden on government budgets.

Annexure A

Table A.1: Review of stated energy RD&D priorities for governments based on announced technology programmes or strategies

Country	Name of Programme or Strategy	Programme or strategy priorities	Share of RD&D spending on priorities	Do stated priorities and actual spending match?
Australia	Clean Energy Initiative	CCS, low emissions coal, renewable energy (specifically solar)	CCS 19%, low emissions coal 8.3%, renewables 22% of which 14.5% is solar (PV 11%)	Stated priorities account for 50% of total energy RD&D budgets
Brazil	Science, Technology and Innovation Platform for National Development 2007 - 2010	biofuels, T&D, hydrogen, renewables, oil, gas, coal and nuclear	biofuels 14%, T&D 23.5%, hydrogen 2%, hydro 11% and nuclear 23%	Stated priorities account for 81% of total energy RD&D budgets
Canada	Energy RD&D programme divided into 9 portfolios	Oil and gas, clean coal, CCS, distributed power, generation IV nuclear, bio-based energy systems, industrial systems, clean transportation, built environment	non-conventional oil & gas 6%, coal 7%, CCS 15.5%, fuel cells 3.66%, EE in industry 3.22%, EE in the transport 2.5% and nuclear 29%	Stated priorities account 67% of total energy RD&D budgets
France	National Strategy for Energy Research 2007	nuclear, renewables, fuel cells, energy storage, CCS, EE in buildings, biofuels, low carbon vehicles	nuclear 50%, renewable energy 11%, fuel cells 3%, CCS 4.5%, EE in buildings 3%, and biofuels 4.5%	Stated priorities account for 80% of total energy RD&D budgets
Germany	Innovation and New Energy	CCS , PV , Solar Thermal ,	CCS 1%, PV 9%, Solar Thermal	Stated priorities account for 60% of

	Technologies 2005	Wind , Fuel Cells and Hydrogen , Technologies and processes for energy optimised buildings , Technologies and processes for use of biomass for energy	1.3%, Wind 5%, Fuel Cells and Hydrogen 5.1%, Technologies and processes for energy optimised buildings 3%, Tech. and processes for use of biomass for energy 1.32%, nuclear 34%	total energy RD&D budgets
Japan	Science and Technology Basic Plan 2006	energy efficiency, nuclear, transport, fuel cells, hydrogen, solar PV and biomass energy, oil, gas and coal	energy efficiency 10% , nuclear 64%, transport, fuel cells 3%, hydrogen 1.4%, solar PV 1.4% and biomass energy .27%, oil gas and coal 9.3%	Stated priorities account for 80% of total energy RD&D budgets
Korea	Green Energy Strategy Roadmap 2009	PV, wind power, fuel cells, LED, Smart Grids, IGCC, Energy Storage, Clean Fuels, CCS, Nuclear Power, Green Cars, Heat Pumps, Energy efficient buildings, CHP, superconductivity	wind power 6.5%, fuel cells 8.6%, IGCC.1%, energy storage 3.8%, CCS 4.5%, nuclear power 16%, energy efficient buildings 5%	Stated priorities account for over 50% of total energy RD&D budgets
Netherlands	Energy Report 2008	biofuels, clean fossil fuels, renewables, sustainable mobility, industrial efficiency,	biofuels .62%, clean fossil fuels 9.3%, industrial efficiency 13%, building efficiency 9% other	Stated priorities account for 68% of total energy RD&D budgets

		building efficiency,	energy efficiency including agriculture and horticultural sectors 13%	
Norway	OG 21 2001 and Eneri 21 2008	Oil and gas, energy systems, renewable electricity, energy efficiency in industry, renewable thermal energy and CCS	Oil and gas 37%, energy systems 4.7%, renewable electricity 15.5%, energy efficiency in industry 2.3, renewable thermal energy 1.2% and CCS 15.6%	Stated priorities account for 76% of total energy RD&D budgets
Spain	National Strategy for Science and Technology 2006 - 2015	energy efficiency, clean combustion, renewable energy, sustainable mobility, modal shift in transport, sustainable buildings	energy efficiency 8.3%, renewable energy 43%, coal 1%, energy efficiency in the transport sector 1%, energy efficiency in buildings 5%	Stated priorities account for 60% of total energy RD&D budgets
Sweden	National Energy Research Programme 2006	energy systems studies, buildings as energy systems, transport, energy-intensive industry, electricity generation and distribution, bioenergy, CHP	energy systems studies, energy efficiency in buildings 4.7%, transport 22%, energy intensive industry, 8.4%, electricity generation and distribution 7.7% and bioenergy 10.6%	Stated priorities account for 70% of total energy RD&D budgets
United Kingdom			wind 10%, ocean energy 4%,	Technologies where the UK has

			CCS 6%	a leading edge capability account for 20% of total energy RD&D budgets
United States	Advanced Energy Initiative 2006	Solar power, biofuels, wind power, hydrogen, buildings technologies programme, clean coal research	solar power 3.5%, biofuels 9.5%, wind energy 1.4%, hydrogen and fuel cells 5.4%, energy efficiency in buildings 2.2%, CCS 4.3% and nuclear 16.2%	Stated priorities of AEI account for 40% of total energy RD&D budgets

Notes: This sample cannot be considered as an exhaustive list, but rather as a showcase of the variety of practices across countries and institutions. Analysis is based on data for the following years: Australia, Canada, Japan, Norway, Spain and the United States: 2007-11; Germany, Sweden and the United Kingdom: 2006-10; Brazil: 2009-10; France: 2007-09; Korea: 2009-11; the Netherlands: 2008-09.

Annexure B

RE enabling policies in India differentiated into direct and indirect policies

Yet another classification of various policy instruments can be into direct and indirect policies providing a link between the policy instrument and the objective at hand.

Table B.1: Overview of various RE enabling direct policies in India

Direct policies for solar PV and wind power				
Financial incentives	**Preferential tax treatment**	**R&D**	**Demand stimulation**	**Manufacturing linked incentives**
• Feed-in tariffs (FITs) • Generation based incentive (GBI) • Reverse Auction Mechanism (RAM) • Bundling of solar power • Viability Gap Funding (VGF)	• Accelerated Depreciation (AD) • Industrial clearances • Tax holiday • Excise duty exemption • Customs duty exemption	• R&D initiatives for solar PV: MNRE; DST; etc. • R&D initiatives for wind power: C-WET; private players • Demonstration	• Renewable purchase obligation (RPOs) • Renewable Energy Certificate (RECs)	• Special investment promotion schemes • Domestic Content Requirement (DCR) • Joint Venture/Foreign Investment/Technology transfer

• Low cost financing		projects		requirements

Source: Ganeshan Karthik et al (2014), Assessing Green Industrial Policy-- The India Experience, The Council on Energy Environment and Water.

Table B.2: Overview of indirect policies/programs in India

Indirect Policies and Programs		
Science and innovation	**Market Mechanisms to Price Carbon**	**Other policies/programs**
• Science, Technology and innovation (STI) policy 2013 • National Clean Energy Fund (NCEF) 2011-2011	• Clean Development Mechanism (CDM) • Performance, Achieve and Trade (PAT) Scheme	• Human Resource building • Power transmission • Renewable Regulatory Fund (RRF)

Source: Ganeshan Karthik et al (2014), Assessing Green Industrial Policy-- the India Experience, The council on Energy Environment and water.

Annexure C

Table C.1: Regulatory context and barriers in which individual instruments for development and deployment of RE technologies are placed

Country	Instrument type	Regulatory environment for RES and barriers
Canada and Canadian Provinces (Ontario and Quebec)	Production incentive; Feed-in-tariff/ premium; Tax incentives; Competitive bidding: Tender (contract price)	• Due to feed-in premium, RES-E largely affected by conventional power market (prices). • Grid connection procedures a barrier to development of RES-E.
France	Feed-in-tariffs; Competitive bidding: Tender (contract price); Tax measures	• Due to fixed feed-in tariff scheme and guaranteed price in tendering, renewable electricity not directly affected by market prices. • Strong administrative barriers --planning procedures (site permissions etc.) -- hampered RES-E market. Some changes therein (regional planning) for wind energy (Law 2005-781) had positive impact on wind power development.
Germany	Feed-in tariff	• High vertical and horizontal integration & domination by few large companies. Congestion at interconnectors & problems of network access -- prevents effective competition for new entrants. • Limited grid capacity in Northern Germany affects wind power production.
Italy	RPS (Quota obligation); Feed-in-tariff	• Production of RES-E under RPS affected by conventional electricity prices. Latter subject to the EU Emission Trading System and excise and carbon tax for fossil fuels. • Complicated authorisation procedure at local level and high grid connection costs.
Japan	RPS (Quota obligation)	• The additional costs for electricity generation from RES, needed to meet this obligation, depend on level of conventional electricity price. • For larger development of wind energy, rules for sharing of costs of grid reinforcement and maintenance of transmission network to be designed.
Netherlands	Feed-in-premium	• To support premium tariff, RES-E production is dependent on conventional power prices. Power and heat prices influenced by an energy tax and by EU Emissions Trading Scheme. • Administrative procedures for RES projects have long lead times. Procedures for large wind and biomass projects (>50 MW) being simplified under new National Project Procedure (RPP, Rijks Projecten Procedure).
Norway	Investment subsidy; Feed-in-premium	• In 1999 a consumer electricity tax was implemented that influenced premium tariffs. • Long administrative procedures, especially for wind power.
Spain	Feed-in-tariff/ feed-in-premium; Tax deduction; Low interest loan	• Grid connection procedures can be time consuming. Grid barriers can impinge on further growth of wind capacity in future.
UK	RPS (Quota obligation); Tax deduction; Investment subsidy	• Conventional power prices influenced by the EU Emission Trading System, the Climate change levy and the Renewables Obligation. • Grid connection procedures are hampering the development of RES-E.
US & US States (California and Minnesota)	Upstream tax credit; RPS (Quota obligation)/ production incentive	

Source: Jager and Rathmann, 2008

Annexure D

Table D.1: Guidelines for best practices in cost calculation, automatic tariff degression and determining time frame of support

Aspect of regulatory process	Best practice
Cost elements and calculation methodology	- Reliance on competitive allocation mechanisms (to the extent possible) to force market players to reveal their real production costs - Cost base calculations to be based on project costs, and to include the following cost elements: o Equipment cost; other investment and planning costs; cost of land; o Administrative costs; operation and management costs; fuel costs (if relevant) o Common cost assessment for grid connection / grid reinforcement; - network-related costs; costs of market integration - Expected revenues: o To be calculated in advance o Adjustments ex-post for differences between the agreed, expected revenues and actual revenues, to avoid over compensation o Technology specific load factors - Caps and floors influencing the level of support to be should be linked to the above cost analysis. - Determination of support levels based on levelized cost estimates
Automatic tariff degression	- Periodic review and adjustment of support levels for new installations o Process of review to be defined ex-ante and be automatic o Determine what constitutes excessive growth and set a volume limit defined in budgetary terms if expenditure is the policy constraint motivating such a cap
Time frame for support	- Limiting support to comparable periods (10/15 years)) or to a pre-set number of full-load hours calculated based on reasonable expectations for capacity utilisation over a defined period. - Longer the time frame, greater the need for flexible, market-adapting instruments

Source: EC, 2013

Annexure D (contd.)

Table D.2: Best practices in the design of select policy instruments

Incentive/ support measure	Countries where the instrument is used	Best-practice recommended
Feed-in-premium	Canada, Netherlands, Spain	- Preference for feed-in-premiums over feed-in tariffs for technologies getting mature - Determining the form of premium - floating (with or without cap) or fixed – as function of desirable exposure of producers to price risk - No payment of premiums for production in hours where the system price is negative or above the level of remuneration deemed necessary - Use of competitive allocation mechanisms to the extent possible for granting premiums - Planned volume based premium reductions for new installations, dependent on when they are approved, connected or commissioned - Regular reviews of premiums for new installations
Feed-in-tariff	Canada, China, Germany, India, Italy, Spain	- Phasing out of feed-in-tariffs - Need for built-in cost-based or expected cost-based tariff reductions for new installations (in line with learning curves and expected future cost reductions in various technologies) - Planned volume based tariff reductions for new installations, dependent on when they are approved, connected or commissioned
Renewable portfolio standard	Italy, Japan, UK, US	- Technology neutral schemes that promote cost efficient deployment or banded schemes to avoid over compensation of cheapest technology and to reflect explicit technology innovation and diversification goals - Schemes based on long-term transparent and planned quotas - Adequate non-compliance penalties to be built in
Competitive bidding	Brazil, Canada, China, France, India	- Tender for support with clear rules that foster genuine competition between bidders - Tenders can be used to allocate different instruments such as feed-in premiums, investment support or green certificates - Tenders need to ensure delivery, e.g. via penalties

Source: EC, 2013 and Authors

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