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Green transition, industrial policy, and economic development

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Abstract: This paper outlines possibilities for a green industrial policy with particular emphasis on developing countries. The question of green industrial policy is investigated by examining experiences and barriers to phasing-in green technologies, focusing on solar PV and energy efficiency as areas for a green industrial policy. The paper outlines a green transition approach to sustain a shift to cleaner and more energy-efficient production processes through clever policy mixes involving elements of push and pull. Rent management and policy adaptation by competent authorities are also part of the model. The paper offers concrete guidance to the question of what governments in developing countries can usefully and realistically do to phase in green technologies given the priorities for development, imperfect institutions for policy-making and implementation, weakly developed innovation systems, and problems of lock-in.

Keywords: green industrial policy, developing countries

JEL classification: O25, O33, Q58

I. Introduction

The development and phase-in of green technologies present specific challenges for industrialized and developing countries alike. *First*, neither international nor domestic market prices reflect the environmental externalities that come with conventional, non-green technology choices. Producers and consumers thus do not receive a cost-based incentive from the market to shift towards green technologies. *Second*, inadequate information on products and amortization periods, uncertainty about benefits, unclear incentives or behavioural barriers impede investments in green technologies. *Third*, green technologies are disadvantaged by the adaptation of suppliers and users to existing technologies and the continuous investment in non-green technologies which reinforce the lock-in of socio-technical systems (Kemp, 1994; Unruh, 2000, 2002). This is fortified by economies of scale (more users of a technology lower production costs)

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and network effects (interdependency of technologies, infrastructure, and industries over time) (Unruh, 2002). *Fourth*, the availability and management of different sources of finance may be a problem for green technologies (Mazzucato and Semieniuk, 2017, this issue).[1] The development and use of alternative technologies and systems thus face serious problems, in the form of political opposition from incumbents and short-term costs sizing up against (uncertain) long-term benefits.

These challenges of market failures and lock-in particularly apply to radical systemic changes, which require changes in the institutional environment and long periods of sustained policy support (Kemp, 1994; Foxon, 2007; McDowall and Ekins, 2014). Developing countries face the additional challenges of more limited resources (financial, institutional, skill) and fewer experiences with state-driven technology development and phase-in. While lock-in effects may be weaker in some cases where hardly any technologies exist yet, market failures may be more pronounced in others due to stronger information asymmetries and cost barriers.

Our goal is to identify concrete options for *what governments in developing countries can usefully and realistically do to phase in green technologies by learning from more advanced countries*. In investigating the question, we look at successful phase-in cases in industrialized countries (Germany, Netherlands) and emerging economies (China, India).[2] The countries selected all have specific phase-in programmes for green technologies but different financial and institutional capacities.

This paper outlines useful elements of a green transition approach for developing countries with special attention to difficulties involved. We argue that phasing-in of green technologies in developing countries is less about discovering new technological niches and more about *utilizing the opportunities already present that coincide with development objectives*. Few developing countries can financially nurture infant industries into world-class industries. For the purposes of this paper, it is therefore useful to look at sectors with a fairly established set of technologies available on the global market that can be adapted to local requirements. We identify renewable energy, particularly solar photovoltaic (PV), and energy efficiency as such fields. Both are constrained by various different market failures, uncertainties, and situations of lock-in. Renewable energies have to be phased in against a strong lock-in of fossil fuel-based electricity and heating systems in most countries. Prices are often still not on par with conventional grid-based electricity. The implementation of energy efficiency suffers primarily from inadequate, non-transparent pricing and underinvestment, but also from information failures and behavioural barriers. Thus, government intervention for phase-in is required in both sectors.

It is believed that a transition approach is useful for taking up the capacity development issues with an eye to two critical issues for a transition: the possibilities for change and the factors that keep it back. Attention to both elements (in an institutionalized transition process) helps to make better policy choices (fitting with needs and opportunities), avoid inefficiencies, deal with opposition from incumbents, and go beyond incremental change.

[1] In theoretical terms, green technologies suffer from incentive-based market failures, information-based market failures, imperfections in the market for finance, and problems of lock-in as a system failure (Kemp, 2011).

[2] The choice of cases is based on investigations we were involved in. They have not been systematically selected.

The structure of the paper is as follows: section II describes reasons for using a transition management approach by summarizing the transitions management literature. It gives a brief overview of potentially relevant factors for managing transitions in developing countries. Section III reveals which of these factors have been important in existing phase-in processes. Five policy examples are discussed: energy efficiency in buildings in Germany, industrial energy efficiency in China, energy efficiency in India and solar PV in India, and transition management in the Netherlands (renewable energy and energy efficiency). The final section specifies key elements of a green transition approach for developing countries by drawing on the lessons from the five examples.

II. Phasing-in green technologies from a transition management perspective

Innovation is a collective process involving learning and adaptation. Knowledge of market opportunity is crucial to innovation, but so is context. Competition leads companies to innovate, but, as noted in 'systems' approaches to innovation (Smith, 2000; OECD, 2002), no firm or researcher can innovate on its own: while individuals certainly can invent, only organizations can innovate, as innovation requires the combination of various types of knowledge and resources. As noted in the first section, eco-innovation depends on government policies to deal with market failure and system failure problems (Horbach *et al.*, 2012), but such policies suffer from political economy problems and the related problem that 'decision-making responsibilities are often fragmented—between economic and environmental criteria, between energy and water supplies, and between value-chain stages, especially across companies' (Levidow *et al*., 2016, p. 192).

Through its lineage in innovation studies,[3] the transition management literature offers many starting points to overcome lock-in and market failure and to deal with uncertainty and vested interests in public decision-making (Nill and Kemp, 2009). However, it still requires clearer operationalization for developing countries. This section outlines prospective key elements for such an operationalization by clarifying the goals, design principles, and tools of transition management. We consider the government's will to design and support phase-in as a given, i.e. political will to intervene should exist already. Two other conditions for a green transition approach are: the presence of innovation opportunities fitting with the needs and capabilities of users (Fagerberg and Shrolec, 2008) and capabilities on the part of policy-makers to craft appropriate policies in the face of uncertainties and information asymmetries (Mytelka *et al.*, 2012).

While a transition management approach is neither the only approach to phasing in green technologies nor failure-proof, it offers more flexibility and options for policy learning than other approaches, such as specific innovation support, preferential trade mechanisms to advance technology diffusion, or rent management (see Lütkenhorst *et al*. (2014) for an overview).

As described in Rotmans *et al.* (2001) and Kemp *et al.* 2007), transition management seeks to overcome a situation of lock-in and market failure by co-producing and

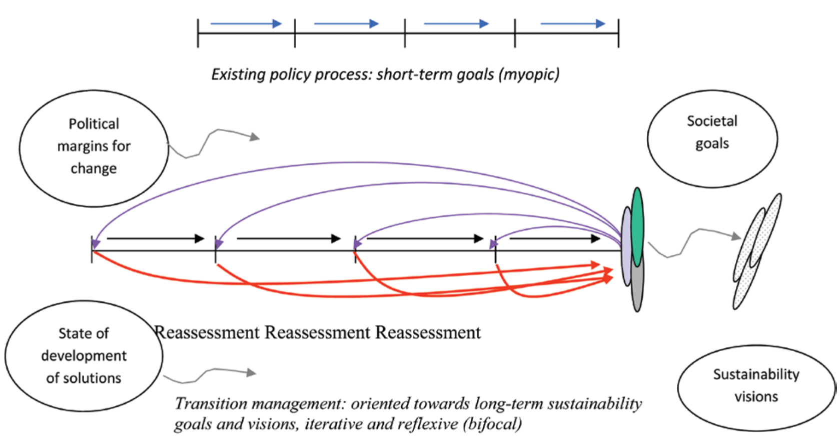
[3] A discussion of transition management and the socio-technical transition literature is offered by Markard and Truffer (2008), Kemp (2009), Meadowcroft (2009), and Smith *et al.* (2010).

coordinating policies step by step with clear targets and programmes for system innovation. The aim of transition management is to accelerate a green transformation of sectors by utilizing innovation possibilities and designing policies that foster private investment into those opportunities. For the phase-in process, transition management relies on the development of a long-term vision, the definition of interim transition goals and pathways by involving relevant actors across different levels, experimental programmes and projects, and mechanisms of policy learning (Kemp *et al.*, 2007; Loorbach 2010). Transition management aims for the complementary expansion of institutional capacities and technology-related capabilities. Transition management assigns an active role to government in mobilizing resources and interests in society to orient change in desired directions (Meadowcroft, 2009). This is done through the use of long-term visions and goals and short-term policies aligned to the goals and to short-term possibilities (Figure 1).

The steps of transition management are: the choice of strategic, long-term visions; the design of interim goals; strategic niche management; and policy adaptation on the basis of policy learning. Policy coordination and evaluation are transversal elements. The visions should be aspiring in combining user benefits with societal benefits. The clarification of visions and long-term goals serves the important purpose of giving direction to investors, innovators, and consumers. Visioning exercises provide the desired direction of the transition (e.g. a renewable energy-driven economy).

The design of interim steps is based on long-term desirability of system changes and short-term possibilities. Such choices should be made in consultation with society, where 'the right model lies between arm's-length and capture' (Rodrik, 2014, p. 485). Drawing on the idea of 'embedded autonomy' (Evans,1995), Rodrik assigns a positive role to the embeddedness of policy in business, consisting of 'strategic collaboration and coordination between the private sector and the government with the aim of learning where the most significant bottlenecks are and how best to pursue the opportunities that this interaction reveals' (2014, p. 485). Transition arenas (Loorbach, 2010), deliberation councils, supplier development forums, search networks, regional

Figure 1: Current policy versus transition management



collaborative innovation centres, investment advisory councils, sectoral round-tables, private–public venture funds (Rodrik, 2014) are possible forms of engagement of government in business networks to obtain relevant information and capabilities to formulate feasible economic goals without political capture (Evans, 1995). However, policy and research suggestions from platforms have to be critically assessed in terms of concerns related to (i) whether these policy and research suggestions arise from healthy embedded relations between public and private actors (arm's length vs capture) in identifying barriers to eco-innovation, (ii) whether these policies, mixes, and research suggestions insert an element of discipline and predictability in policy, and (iii) whether the public interest is safeguarded by accountability and legitimacy in design and implementation phases. Omniscience on the part of the government is not required: 'what is needed is a set of mechanisms that recognizes errors and revises policies accordingly' (Rodrik, 2014, p. 472).

The operational part of transition management consists of adaptive programmes, the alignment of different policy fields to each other, and the use of strategic niche management (SNM) for promising technologies.[4] Ways to align science policy, innovation policy, and sector policy to transition goals are:

- *in science policy*: the use of sustainability assessments of system innovations, transition road mapping, backcasting;
- *in innovation policy*: the creation of innovation alliances, R&D programmes for sustainable technologies, the use of transition-experiments, and alignment of innovation policies with environmental policies;
- *in sector policy*: niche policies (through procurement, regulations, or the use of economic incentives), the removal of barriers to the development of system-innovations, and formulation of long-term goals and visions to give direction to research and innovation.

Policy choices are made 'along the way' on the basis of learning experiences at different levels. The transition management approach acknowledges that a successful phase-in of green technologies requires a long time-span with several cycles of adjusting policies until full implementation of the desired vision is reached. Explicit policy learning rounds are planned to evaluate which interim goals have been achieved, whether the process is dominated by certain actor groups (vested interests), and how regulations, procedures, and goals need to be adjusted to match long-term and short-term concerns (Rotmans *et al.*, 2001). Ideally, this leads to gradual change that minimizes social resistance. A transition management policy does not make environmental policy obsolete but adds an innovation-oriented programme to it.

Overall, transition management does not prescribe a particular path for phasing-in green technologies, but offers a framework for exploiting possibilities for green development in a forward-looking, adaptive way. Environmental protection benefits can be combined with economic benefits in such a green transitions approach. The next section analyses different successful cases to identify common and unique elements

[4] SNM is the creation and management of protected spaces (niches) for promising technologies by means of experimentation with the aim of learning about the performance, effects, economic viability, and social desirability of the technology and to use this knowledge to inform private and public (support and control) policies that are needed for the further development and rate of application of new technologies and technology systems (Kemp *et al.*, 2000, p. 170).

of phasing-in from a transitions management perspective that could be particularly important for developing countries.

III. Examples of successful phase-in programmes

This section describes five examples of relatively successful phase-in programmes. Each of them is introduced by a brief explanation of why such a programme was required. This is followed by a description of what has been done and achieved. Reasons for success and difficulties encountered are summarized at the end. The German, Chinese, and Indian cases are all sector-specific examples. The case study of the Netherlands showcases a more systemic approach on an aggregated level, encompassing the whole energy sector. For developing countries, the choice between a more selective or systemic approach depends on the state of the sector (market and readiness to innovate, number and interest of actors, technologies already available), the linkages between actors and market segments (could there be win–wins by a systemic approach?) and the degree to which technologies can be locally adapted in line with development objectives. In our view, more developed market segments with potential for strong linkages to others such as solar PV modules are more likely to qualify for a systemic approach.

(i) Energy efficiency in buildings in Germany

In Germany, buildings account for around 35 per cent of final energy consumption (heating, ventilation, and warm water provision; NAPE (2014)). Roughly 75 per cent of residential buildings are older than 30 years and require improved heating and insulation systems—sunk costs are thus widespread. In spite of existing regulation in many countries, energy efficiency in buildings is difficult to achieve, especially in older buildings that require refurbishment. The following market barriers exist in industrialized and developing countries alike (Liu *et al.*, 2010), calling for governmental intervention:

- a lack of appraisal by the market of investments in more energy-efficient buildings and sunk costs in old buildings (cost–benefit distortion);
- split incentives among key stakeholders (e.g. building owners may have other interests than tenants);
- coordination among building sector's many stakeholders;
- lack of information and knowledge (e.g. on buildings' energy performance);
- complexity of delivering more efficient buildings due to a variety of technologies and measurement challenges.

The German government's approach to increasing energy efficiency in both old and new buildings over time has three pillars: regulation (mainly command-and-control instruments), financial incentives, and information to build trust. The three pillars were designed to complement and mutually strengthen each other (Schröder *et al.*, 2011; Schimschar, 2013). Moreover, the different instruments are linked to renewable energy measures to form a coherent energy policy package. By way of these measures, primary energy consumption in buildings will be reduced by 80 per cent by 2050 compared to 2008.

Germany's first thermal insulation *regulation* was developed early on in 1977, but political momentum towards implementing mandatory standard-setting only gained ground in the 1990s. Currently, the energy saving ordinance (Energieeinsparverordnung, EnEV), comprising the German building code, and the act on the promotion of renewable energies in the heat sector provide the regulatory framework. The German energy saving ordinance was introduced in 2002, in line with the European directive on the energy performance of buildings (also 2002), revised and tightened in 2007, 2009, and 2013/14. The EnEV 2013 is the first regulation that outlines a stepwise tightening of construction law to a carbon neutral standard by 2021 (El-Shagi *et al.*, 2014, p. 10). Standards are thus sequentially introduced and tightened over time.

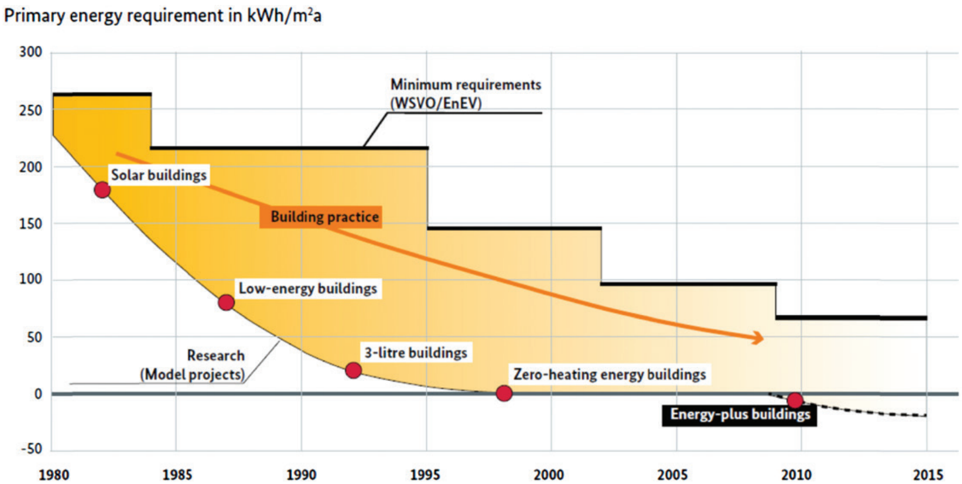
Financial incentives to comply with regulations and voluntary mechanisms are provided in the form of subsidy programmes for the refurbishment and construction of new buildings by the public bank, Kreditanstalt für Wiederaufbau (KfW), and for heating with renewable energies (Marktanreizprogramm zur Nutzung erneuerbarer Energien im Wärmemarkt, MAP). The government's 2004 CO_2 refurbishments programme includes two subsidized loan schemes: the KfW programme for energy-efficient refurbishment and the KfW programme for energy-efficient new buildings. Grants and loans are staggered according to the degree of energy efficiency; the more energy-efficient the building is, the higher the grant and the more favourable the repayment conditions for loans. This approach covers the whole range of technically feasible options on the market; it is revised regularly to increase energy efficiency. Preferential loans with low interest rates for energy efficiency can be combined with loans for a new heating system based on renewable energies.

Information-based programmes, such as the energy performance certificate for buildings (energy label) and the targeted promotion of the energy efficiency-related jobs and expertise, complement the policy package. Various information and trust-building measures for home-owners, tenants, experts, and construction industry support knowledge exchange and give security for stakeholders in the market.

The sequential introduction of standards presents a particularly interesting element in the German three-pillar approach. It provides the market with both clear signals and sufficient time to adjust. New standards are tested in pilot projects to identify the optimal technology available on the market and revised every few years. While the regulatory framework is being expanded, the national standardization body, DENA, and KfW promote model and experimental projects and commission research to accompany and evaluate running programmes. For example, DENA developed and tested the standards for low-energy buildings on 400 individual projects. KfW subsequently adopted these standards to support an additional 5,000 prototype buildings (Schröder *et al.*, 2011, p. 35).

The German energy-efficient building programme has had positive effects on energy consumption, regional value chains, and investment dynamics in the sector. The sequential introduction and tightening of regulations accompanied by research and model projects have led to substantial reductions in primary energy consumption over time (Figure 2). Figure 2 shows the sequential tightening of regulatory requirements, pushing energy-efficient building practices towards more efficiency (minimum requirements WSVI/EnEV, above in the Figure). The continuous development and testing of most efficient buildings in model projects (e.g. solar buildings, zero-heating buildings) create a pull-effect on the market (below in the figure). The actual building practice lies

Figure 2: Long-term phase-in of building standards



Source: National Energy Efficiency Action Plan Germany, 2014.

in between the respective regulation at the time and the most efficient technologies possible, becoming more energy efficient over time.

In 2011, the energy efficient refurbishment of existing buildings had regional value chain effects of €14 billion and generated about 287,000 full time jobs (Weiß *et al.*, 2014). Since 2006, 3.7m dwellings could be refurbished or newly built in an energy-efficient manner with an overall investment volume of €182 billion. On average, every public euro invested in KfW subsidy programmes between 2006 and 2011 generated €10–12 of private investment (Weiß *et al.*, 2014). Additionally, a strong indirect effect on regulation on innovation can be witnessed. Investors in the high-end housing market segment strongly react to a narrowing technology gap compared to adopters in the low-quality market, even if their own performance is far from being at risk of being affected by regulation in the near future (El-Shagi *et al.*, 2014, p. 21). These results confirm a weak form of the Porter–Van der Linde hypothesis on regulation and innovation (Ambec *et al.*, 2011).

Overall, the continuous revision of regulation and incentives as well as the combination of different types of measures in a policy package are responsible for the success of the German programme thus far. A high degree of collaboration between actors in the policy process, the integration of experimental pilot projects and accompanying research that fostered feedback and learning cycles, as well as the gradual tightening of requirements in all fields supported the achievements greatly. Finally, energy-efficiency measures were explicitly coupled with the promotion of renewable energy usage in buildings.

(ii) Industrial energy efficiency in China

The Chinese industry is locked into an unsustainable, fossil fuel-based path. Industrial energy consumption is increasing significantly in China: from 34 per cent in 1990 to approximately 70 per cent of total national energy consumption today; 77 per cent of all electricity is produced from coal. Since energy prices for industry are negotiated regionally, the market does not send a consistent signal to invest in energy efficiency. Before the Chinese government started its programmes, companies hardly invested in energy efficiency. The government employs a 'state-signaling approach' (Harrison and Kostka, 2014) where the central state provides target and guidelines to local governments, but keeps policy goals broad enough to allow for local interest alignment and bundling of policies and incentives.

In 1995, the government published a guideline for energy management in industry, which already indicated companies that future regulation was to come. Since the 1980s, China has been monitoring energy use in industry, but concrete interest in energy management systems in industry only started to rise in the early 2000s (Zhou *et al.*, 2010). Following the introduction of the Energy Conservation Law in 2001, the government developed a comprehensive package of mandatory and voluntary policies and measures aimed at advancing energy efficiency and energy saving. The Medium and Long Term Energy Conservation Plan was published in 2004. In the 11th Five Year Plan (2006–10), command-and-control regulations were combined with taxes and subsidies—sticks, carrots, sermons, and prohibitions (Yang *et al.*, 2015, p. 21).

Sticks

The Differential Electricity Pricing Policy consists of four categories with different surcharges for industries that increase with consumption. More efficient enterprises thus pay less. Between 2004 and 2010, these types of taxations were subsequently increased. However, initial charges were found to be inefficient in terms of increasing energy efficiency investments. This was due to heterogeneous, counteracting local policies and fluctuating selling prices and other production costs (Yang *et al.*, 2015). To phase out inefficient enterprises, the surcharge in this category was increased by a factor of four over time.

Carrots

Companies can receive a reward of 250 yuan per tonne of coal equivalent saved through technical upgrading and engineering projects or the Ten Key Energy Saving Projects. A number of R&D support strategies for different business sectors as well as financial compensation for technical retrofitting and the phasing-out of small and inefficient industrial plants exist.

Sermons

The 'Top 1,000' energy savings agreement between key industry ('sermons') and government was voluntary when first introduced in 2006 and gradually extended to provincial and local levels. In 2012, the programme became mandatory and was expanded to the 'Top 10,000'. It requires companies to annually send their energy use statistics to government and to meet national and international standards. The Top-10,000 programme and its combination with energy management systems helped to raise awareness among provincial authorities and top-level management. But the implementation of it is impeded by a lack of understanding in non-Top 10,000 companies, a lack of funding and adoptable technical means (Goldberg *et al.*, 2011; Li *et al.*, 2014). The proper adoption of energy management systems—either the national standard or ISO

50001—can actually make it easier for companies to comply with regulations and monitoring schemes. The electricity saved may then qualify the business for a different electricity price category (see 'Stick' above).

Prohibitions

The 2006 Plan on Energy Conservation and Emissions Reductions sets targets for the closure and phasing-out of small and inefficient production facilities. Several provincial and local governments, however, prioritize local economic development and jobs. They protect local factories from closure or let them operate unofficially, thus opposing national policies (Yang *et al.*, 2015).

China's approach to industrial energy efficiency has led to the envisioned reduction of the economy's energy intensity by 20 per cent by 2010, but progress since has been rather slow. The implementation of national energy policies relies on creative bundling of interests, incentives, and policies by local governments and administration to minimize opposition of local players (Harrison and Kostka, 2014). The government is struggling to achieve structural change that actually replaces less energy-efficient technologies and products with more efficient ones across all sectors during the 12th Five Year Plan (2011–15; Ke *et al.*, 2012). Official documents state that 340m tonnes of coal equivalent have been saved under the Ten Key Projects programme up until 2010.[5] A gradual, cautious introduction of a carbon trading system is now envisioned to complement existing measures. The diffusion of these measures to medium and small energy-intensive companies presents a challenge in the next stage of the phase-in process in China.

Concerning industrial policy effects on the supply side, the market for energy efficiency consultants and energy service companies (ESCOs) has been developing since 2006. In the years 2010–15, this market grew by 31.9 per cent annually, employing 654,000 people in approximately 2,600 companies by 2015 (IbisWorld, 2015). In spite of these numbers, ESCOs have been criticized for not working effectively enough due to imperfect business models, asymmetric information, high transaction costs, lack of ability to build a relation of trust to customers, and lack of skills, especially in new ESCOs (Kostka and Shin, 2013). Energy auditing capabilities vary greatly throughout the country. While the market is developing well, it is far from having reached maturity and use of its full potential across the whole country.

A critical element of the Chinese policy package and path was the shift from voluntary agreements and incentives to comprehensive mandatory requirements for large industry. This led to an impressive achievement of energy consumption reductions in a rather short time span, whilst establishing the topic firmly on the political agenda and creating local jobs. The shift from voluntary to mandatory measures was based on an assessment of the actual capabilities of leading industry to reduce energy intensity. Fiscal incentives are used as part of the broader energy efficiency policy package, but are not yet interlinked with other mechanisms to maximize the effect. The existing political economy challenges between central and local governance levels indicate that awareness, capabilities, and interests of different actors require *ex ante* consideration in the planning of phase-in of green technologies. This is particularly important for developing countries facing similar challenges.

[5] Ke *et al.* (2012) doubt this figure. Due to measurement and calculation challenges, it is difficult to ascribe effects to specific programmes.

(iii) Energy efficient labelling of appliances in India

In India, residential energy demand accounts for 45 per cent of the country's primary energy consumption—80 per cent of which can be ascribed to only five appliances: ceiling fans, TVs, lighting, refrigerators, and air-conditioners. The consumer appliance market grew at an annual average of 13 per cent between 2003 and 2013, increasing overall energy demand (Jairaj *et al.*, 2016). Inefficient appliances have a lower price on the market and consumers often lack the information that more energy-efficient appliances with a higher purchase price save more on their electricity bill (amortization). Manufacturers have no incentive to invest in the development of more efficient, higher priced goods that they fear consumers will not buy (Chaudhary *et al.*, 2012). These market failures need to be overcome to use India's projected potential to save up to 240 TWh of electricity through energy efficiency standards by 2030 (Letschert *et al.*, 2013). India has adopted a 'market-plus approach' (Harrison and Kostka, 2014). The rules of the market are defined by the state, but the limits of state capacity to ensure widespread implementation were acknowledged from the start, recognizing that different actor groups with diverging interests needed to be brought on to common ground (Harrison and Kostka, 2014).

In 2001, the government set up the Bureau of Energy Efficiency (BEE) with the mandate to develop an energy efficiency programme for household appliances and lighting, buildings and industries, including standards and labelling. By the time of its introduction in 2006, it had been clear to stakeholders for several years that a standard and labelling programme for appliances was to be introduced. In the planning and design phase, extensive consultations were held with manufacturers, utilities, standardization bodies, and other stakeholders. The programme consists of a star-rating scheme based on minimum energy performance standards set by BEE (1–5 stars). Labels are voluntary at first, then made mandatory once labelled products reach 50 per cent of annual sales. Facilities for testing the appliances were developed to allow for independent testing, and market pull was created by mandating government procurement at the highest star ratings (Chaudhary *et al.*, 2012). BEE plans to gradually tighten the performance standards for the stars over time in an attempt to promote product innovation.

In the initial phase of the programme, standards and labels were designed to include a majority of the market to support consumer understanding with the clear communication that standards would be ratcheted up. Extensive consumer outreach and information was provided to build up the labels as a brand. Manufacturers self-certify the products by adopting the approved testing procedure and are thus responsible for the accuracy of the labels. Due to understaffing, BEE has outsourced the process of collection, verification, and processing of self-certificates to a consulting firm (Jairaj *et al.*, 2016). BEE carries out market assessments regularly to understand market penetration, but these are not publicly available, making it difficult to judge how much the diffusion of efficient products has advanced in each product category (Khandari, 2011). Since the BEE has been functioning as both the designer of programmes and facilitator to state governments and businesses at all levels, the reliance on outsourcing services and the development of an ESCO market soon became inevitable. While this ESCO market is evolving, it is still largely located in Delhi, Mumbai, and Pune (Harrison and Kostka, 2014). Future challenges across India include the establishment of trusted client–ESCO relationships as well as increasing the attention of public agencies—as role models—to electricity price and expenditures. Co-benefits are the key argument for energy efficiency in India, thus bundling interests of diverging and possibly opposing stakeholders (Harrison and Kostka, 2014).

In 2016, frost-free refrigerators, tubular fluorescent lamps, room air conditioners, and distribution transformers progressed to mandatory labelling; 17 additional products are under the voluntary labelling scheme. In December 2012, the target of the standards and labelling programme had already been surpassed: 7,766 MW of new generation capacity addition were avoided, greatly surpassing the 3,000 MW estimated (BEE, 2014). Market uptake for appliances with higher levels of efficiency (4 and 5 stars) has generally been slower than for medium-level appliances (Jairaj *et al.*, 2016). While the initial phase of the programme has been highly participatory with a clear roadmap, the frequency of review and elevation of standards today is not sufficiently clear to all manufacturers now. Consumer awareness programmes have achieved growing brand recognition of the star label, but the share of inefficient devices is still significantly higher than the one for higher star-labelled ones. The absence of a targeted communication plan limits the full outreach potential, for instance via civil society organizations (Jairaj *et al.*, 2016). Moreover, initially higher costs of efficient devices and a limited willingness to pay remain challenges (BEE, 2014). These factors currently undermine the building of a broad societal acceptance of energy-efficient appliances across all of India.

The factors responsible for the success of the programme thus far are: a sophisticated understanding of the local needs, the sector, and institutional context as well as extensive consultations with a range of stakeholders (Chaudhary *et al.*, 2012, pp. 58–9). The idea of embedded autonomy and the communication worked well in this case. This ensured a robust selection process and the buy-in of all relevant actors, including incumbents and innovators in the system. The gradual tightening of standards and labels in line with the roadmap initially provided to stakeholders was also helpful, but currently needs to be improved so that the process is clear to all relevant stakeholders.

(iv) Solar PV in India

India has a high solar radiation and sufficient amounts of open space in several of its states. There is a vast potential for both on- and off-grid solar energy, offering both energy and socio-economic development opportunities. However, the energy system has been locked into fossil fuels with a strong local coal industry for a long time. Additionally, high costs of solar panels and a lack of regulatory certainty used to discourage industry's investments in the sector. The central government's solar PV programme sought to change this. It can be understood as an example of strategic niche management in the sense of the transition management literature.

An interest in solar policies had already begun to arise in the states of Gujarat and Rajasthan in the early 2000s. In 2008, the Jawaharlal Nehru National Solar Mission (JNNSM) was announced as part of the National Action Plan on Climate Change. It provides a long-term vision with clear targets to be achieved in each of its phases. The different phases include a comprehensive set of measures: preferential feed-in tariffs, renewable energy purchase obligations and certificates, tax incentives, preferential loan schemes as well as local content requirements to support the build-up of national manufacturing capabilities. In terms of targeted innovation support, government institutions receive 100 per cent and the private sector 50 per cent R&D project subsidy for advancements in solar energy (Sahoo, 2016). Federal legislation is complemented by state level incentive programmes.

The most interesting element of the NSM is the reverse bidding approach in auctions that created competitive feed-in tariffs. In a first test phase, the government offered a fixed feed-in tariff for projects up to 5 MW, before requesting companies to offer discounts on the previous tariff in a second phase with projects up to 20 MW. Winning bidders were offered 25-year guaranteed tariffs. This approach has been implemented in different states. The phased-approach offers explicit options for policy learning, while also signalling long-term stability for investors since measures such as the feed-in tariff give guarantees (Altenburg and Engelmeier, 2013; Quitzow, 2015).

Since 2009, the start of the National Solar Mission, India's installed solar capacity increased from virtually zero to 5,130 MW in January 2016. The solar energy market has been growing at a rate of more than 300 per cent in the last 5 years. Solar tariffs across states have been reduced from about INR 12.5 per unit in 2010–11 to about INR 5.5 per unit in 2014–15 on average (IRENA, 2015). The feed-in tariff and the local content requirements, in particular, have stimulated the growth of a strong domestic market, even though the World Trade Organization recently ruled that India is violating global trade rules with the latter (February 2016). In 2014, approximately 125,000 people were employed in the solar PV sector in India (both on- and off-grid). However, only 28 per cent of India's PV module production and 20 per cent of its cell manufacturing capacity were used due to stiff competition from China, the United States, Japan, and Germany.

The oversupply of modules and cells on the world market as well as the Indian government's decision to still allow the import of crystalline cells and thin-film technology in different phases of the NSM impeded the development of a national thin-film industry. Moreover, the domestic market is not sufficiently linked to export performance: India's industrial policy does not take the traditional export orientation of India's solar PV industry into account (Quitzow, 2015). The solar PV market is therefore a positive example for the phasing-in of green technologies, but not necessarily for the promotion of local green industrial production. The increase of solar energy in India's energy mix turns this into a positive example, nevertheless, as the alternative would mean even higher greenhouse gas emissions from the country and fewer options for off-grid electricity in poor areas.

Overall, the Indian government's sequential approach with a clear roadmap as well as packaging of different measures have been advantageous to the phasing-in of solar PV. The key to India's successful seizing of opportunities this far has been the creation and management of rents (Altenburg and Engelmeier, 2013). At a stage where the market for a new technology is not fully developed, the government provided investors with above average returns until technologies became commercially viable. Providing the adequate level of rents at any given time, without supporting political capture or wasting budgets, presents a challenge (Altenburg and Engelmeier, 2013). Given the developments on the global solar market, India is currently facing this challenge as well. Still, the phase-in of solar PV with a feed-in tariff can count as an example of strategic niche management (Kemp *et al.*, 1998; Caniëls and Romijn, 2008).

(v) Transition management in the Netherlands

The Dutch transition management approach for sustainable energy is a systemic green industrial policy approach. Its goal was to stimulate new business in sustainable energy and foster a broader energy transition. To develop such a systemic green industrial policy, the traditional divide between the Ministry of Economic Affairs and the Ministry of Environment had to be overcome. This happened in a deliberative process which resulted in the coproduction of the transition management framework (for details of the dialogue between government and science see Kemp and Rotmans (2009)). It envisioned the set-up of seven transition platforms, the development of a transition action plan, and different transition paths explicitly entailing experimentation, capability-, institution-, and network-building.

The transition approach officially started in 2002 with the project implementation transition management (PIT) of the Ministry of Economic Affairs. In 2004–5, the energy transition process gained speed through the establishment of four *transition platforms* (new gas, green resources, chain efficiency, and sustainable mobility). In these platforms individuals from the private and the public sector, academia, and civil society come together to develop a common ambition for particular areas, develop pathways, and identify useful transition experiments. In 2006, two additional platforms were established (sustainable electricity supply and built environment). The transition path energy producing greenhouse became a platform of its own in 2008.

The suggestions of the transition platforms lead to a *transition action plan*, containing the following goals:

- −50 per cent CO_2 in 2050 in a growing economy;
- an increase in the rate of energy saving to 1.5–2 per cent a year;
- the energy system getting progressively more sustainable;
- the creation of new business.

Following the work of the transition platforms, 31 *transition paths* have been explored through *research and innovation experiments*. These included biomass for electricity, clean fossil, micro cogeneration, and energy-producing agricultural greenhouses. The government acts as a process manager, dealing with issues of collective orientation and interdepartmental coordination. It also takes on a responsibility for the undertaking of strategic experiments and programmes for system innovation.

The transition approach went beyond technology support. The *creation of capabilities, networks, and institutions for transitional change* through agenda-setting, new partnerships, and instruments was equally important, leading to vertical actor and cross-sectoral policy coordination. The Interdepartmental Project Directorate Energy transition (IPE) presents one example that had a central role in the process. It was set up in parallel to the transition platforms for this purpose. It plays an important role in 'taking initiatives', 'connecting and strengthening initiatives', 'evaluate existing policy and to act upon the policy advice from the Regieorgaan and transition platforms', to 'stimulate interdepartmental coordination' and to 'make the overall transition approach more coherent' (VROM and EZ, 2008, p. 10)

The front-runners desk, also created in 2004, presents a second, particularly interesting example (see Table 1). It was set up to help innovative companies with problems encountered and to help policy to become more innovation friendly. Problems varied

Table 1: Overview of functions of the front-runner desk for innovators and policy

Functions for innovators	Functions for policy
Obtain financial support from existing instruments	To make existing instruments more conducive for innovation
To get into contact with relevant agencies and government people	To improve policy coordination between ministries and within ministries
Overcoming legal problems and problems with permits	To stimulate case-sensitive implementation of existing and new policy
To widen their network and strengthen the organizational set-up of the innovation trajectory	To stimulate policy development in areas of the innovation chain not well covered by policy
Business support and public relations help for the successful market introduction	To be serviceable to business in a case-sensitive way

Source: Weterings (2006).

from difficulties with getting financial support (from government or private finance) to problems with getting permits. Between January 2004 and March 2006, 69 companies approached the desk to discuss problems. In 59 per cent of the cases, the problems were solved thanks to the intervention of the desk; in 12 per cent of the cases, the companies could not be helped; and in the remaining cases (29 per cent) the desk was still dealing with the issue at the time of the evaluation.

In 2011, the transition management was officially abandoned as part of an overhaul of innovation policy by the Minister for Economic Affairs who was pro-nuclear and pro-fossil fuel use. Unofficially, however, it continued in the form of a green deal approach, support for a biorefinery plant, and a €50m programme for zero-energy buildings. For electric mobility, an action plan with a budget of €65m euro was created (van de Loo and Loorbach, 2012). In 2013, a sustainable energy covenant ('Energieakkoord voor duurzame groei') was signed by employer organizations, worker organizations, the financial sector, non-governmental organizations (NGOs), and the national government in which the parties involved agreed to invest and work towards in energy efficiency and renewable energy. It is an attempt to involve business and societal organizations in the energy transition.

The effects of transition management are difficult to pin-down. The experiences with the front-runner desk are very positive and the business of electric mobility received a big boost. Between 2008 and 2013, the economic value of the e-mobility sector in the Netherlands showed a sixfold increase in gross value added from e-mobility: from 20m to 120m by 2013. The number of jobs in this sector increased from 300 to 1,600 full-time equivalents (van der Beesen *et al.*, 2014). The effects of the covenant for sustainable energy are unclear as an evaluation is pending, but progress appears to be low, due to the weak instrumentation of the approach.

Our assessment of the transition management approach is that it helped to explore alternative trajectories, and opened avenues for system innovation in the field of green energy. A very useful policy innovation was the front-runners desk. Overall, the transition management approach had several useful elements but also suffered from serious problems. One problem was that the liberalization of the energy markets worked against the energy transition project, leading to policy inconsistency (Kern and Howlett, 2009). A second problem was the large influence of incumbents from the gas and oil regime in the transition platforms. The support of research and innovation in sustainable technologies proved easier than the phase-out of non-sustainable technologies, but the political economy element of this makes this a difficult task for any country (Chang, 1996; Johnson *et al.*, 2014).

IV. Conclusion: key elements of a green transition approach for developing countries

In this paper, we describe experiences with phasing in green technologies in developed and developing countries and outline a green transition approach. While this paper focuses on examples from solar PV and energy efficiency in China, Germany, and India, other green technologies may also be suited for a broader green transition approach in a developing country. Each situation requires its own approach, but the following six elements are seen as useful elements, which help to enhance the chances of success. The importance of these elements is brought out by the cases discussed and in line with innovation system dynamics literature (especially the literature on transition management) and political economy studies of industrial policy that emphasize the importance of rent management and the need of a competent bureaucracy that is able to deal with information asymmetries (Altenburg and Engelmeier, 2013; Schmitz *et al.*, 2013, Johnson *et al.*, 2014; Rodrik, 2014).

First, pro-active planning on the part of government (in the form of a long-term vision and a clear roadmap with interim goals and steps) constitutes a useful starting point for any transition approach, in providing direction and guidance to innovation actors and investment decisions. The vision and roadmap need to be attractive and communicated early and clearly to investors, innovators, and other stakeholders to identify technologies and innovations and prepare the producers and consumers. The inclusion of relevant stakeholders such as manufacturers, business associations, and standardization bodies at an early development stage is advisable (embeddedness without political capture). *Second*, the selection of options for support and the forms of support should be carefully done, and is best done with the help of independent experts. Subsidy schemes should be time-bound and monopoly rents should be avoided. Auctions are a useful model here. Rent management (for new and old technologies) should be mindful of the politics that operate (the opposition from fossil fuel companies and opposition from within the government), who will use negative outcomes to delegimitize the entire transition project, in an attempt to dissolve it. *Third*, a sequential approach helps to make use of contingencies and lessons, while maintaining a sense of direction. This can take the form of gradual tightening of regulations and standards or the testing in pilot projects before supporting a broader up-scaling. This is connected to the *fourth element*, explicitly including policy learning in the phase-in process to achieve socio-economically acceptable and successful implementation. Policies need to be adjusted to new (market and technology) circumstances and remedy negative effects (in the form of windfall gains for some groups and the occurrence of new problems because of problem shifting). The Chinese and Indian cases have shown that allowing some policy space for strategic bundling of interests at local levels may be an important part of this policy learning. *Fifth*, designing a policy package has been helpful in many of the examples discussed here. This policy package can include both policy-push and market-pull policies as well as R&D, institutional capability, skill and job creation measures, e.g building up a consultancy and certification industry. *Sixth*, adequate implementation control mechanisms need to be put in place. The building and financing of technology-testing facilities and the evaluation of implementation schemes are as important as fostering consumer awareness for an energy efficiency label, for example.[6]

These six elements provide no guarantee for the successful development and phasing-in of green technologies in each and every case. A green transition approach aims at generating 'momentum' for transition processes. It requires capabilities for government and governance which are outlined. The six elements are best viewed as propositions to be further tested and scrutinized.

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[6] The recommendations are in line with those of McDowall and Ekins (2014) who offer the following additional suggestions: the use of mission-driven R&D agencies and institutions to support key technology fields; long-term patient finance vehicles for green innovation; a clearly articulated approach to the life cycle of support, with clear criteria and processes for the withdrawal of support.

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