Political Architecture of India's Technology System for Solar Energy

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This essay makes a case for embedding the analysis of institutions for technological change in an understanding of the politics of markets. In turn, this needs knowledge of institutions and of their relations. The first stage that is needed to explain the retarded development of apparently appropriate solar energy technology in India is developed; and the implications for technology theory, analysis and policy are outlined. India's technology system was created precociously early to facilitate research and development. Technology is available. It is not obstructed by intellectual property rights so much as by the structure of domestic energy subsidies and support measures, the risk aversion of banks and the coordination failures of the system of market- and state-institutions for renewable energy technology. As a result, the state is seriously hampered from acting in the long-term public interest. In general, policy reform may require institutional destruction as well as creation, adaptation and persistence.

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In the climate change policy debates India is a complex force. Along with China, India is key to the 2009 Copenhagen global climate "deal" which is to replace Kyoto – in the analysis of which domestic politics are neglected. While the so-called advanced countries (ACs) see India as a threat in flow terms – an increasingly big emitter of carbon dioxide (CO_2) – and an obstacle to the global deal, India (i e, the state and the media), meanwhile, sees the problem in terms of CO_2 stocks, and India as a victim of the pollution of ACs with small flows if they are calculated *per caput* (Panagariya 2009: 40-44). India, therefore argues, "physician, heal thyself" and appeals for donations to cover large "hospital bills" for technological transfer to India. No matter that India's growth has produced inequality rather than eradicated poverty, that its "technological package" has produced jobless growth rather than mass employment and its consumption patterns at the top end of the income distribution at levels produce CO_2 approaching those of North America (20.6 tonnes per person per annum, or pppa), departing rapidly from the eventual "CO_2-stabilising" world average of two tonnes.[1]

While the main energy demand is for heavy industry – fertiliser, cement, oil, iron and steel, aluminium, paper and construction materials (Neale 2008: 93) over half India's 27,000 villages (487 million people) are still off-grid and depend on state-distributed and subsidised kerosene, on animal and human energy, candles and biomass including cowdung and charcoal. While India's development is conceived as the progressive reduction in the use of renewable biomass for energy, biomass is being rehabilitated for this purpose in the European Union (EU).[2] India's demand for primary energy is expected to leap from 400 m toe[3] to 1,200 m toe by 2030, by which date the per caput consumption of electricity is expected to have tripled from its current 660 kWh/cap (7% of the Organisation for Economic Cooperation and Development (OECD) average) to 2,000 kWh.[4] Currently, 75% of this electricity is generated from coal and lignite, relatively and absolutely the dirtiest sources. They are justified as the resource of preference for India's growth not only because of huge reserves under state monopoly control, but also because of the legitimacy and immediacy of the objective of poverty eradication.[5]

While coal is extolled and the threat of its emissions are used as a bargaining chip in India's negotiations leading to the Copenhagen conference, solar energy has the estimated physical potential for *94% of India's additional electricity needs by 2031-32*.[6] In addition, solar energy can leapfrog grid extension. Its employment multiplier is greater than other forms of renewable energy.[7] It can contribute to national energy security. Its cost (Rs 20-25 per unit in 2009) is thought to be comparable to or less than that of electricity from coal and oil fired generating stations once their externalities and current subsidies are factored in.[8] These hard facts started to be recognised in India during exactly the brief era in the late 1970s, when reeling from the second oil price shock, many OECD governments together with China were also encouraging publicly-funded science to explore alternative energy (Dickson 1988; Martinez-Alier and Schlupmann 1990: 18; Schneider et al 2008). With foresight, the elements of an Indian "technological package" or innovation system were engineered in the 1970s and 1980s on a time-par with Germany and well prior to the shove Rajiv Gandhi gave to the unfolding process of liberalisation.[9]

The curious result is that solar energy at present supplies 0.75% of India's electricity.[10] Just 5% of the Ministry of New and Renewable Energy (MNRE) budget is devoted to solar under the 11th Five-Year Plan.[11]

Meanwhile, fossil fuel (FF) based electricity generation has a very large set of public support measures and subsidies – averaging 150% of the capital costs of projects between 1993 and 2003 (WISE 2008: 73). Since over half the population still does not have access to any electricity (notwithstanding the indirect impacts of sectoral cross subsidies to agriculture), the Indian subsidy as a whole is socially regressive: it benefits the upper income brackets at the expense of poor people and those living in backward regions.

It is in both the national and the global public interest that India develop solar and other renewable energy. While launching India's National Action Plan on Climate Change in June 2008 Prime Minister Manmohan Singh said:

> In this strategy, the sun occupies centre stage, as it should, being literally the original source of all energy. We will pool all our scientific, technical and managerial talents with financial sources to develop solar energy as a source of abundant energy to power our economy and transform the lives of our people and change the face of India.

Yet, six months after this statement was made, India's Integrated Energy Policy plan for renewables as a whole to account for no more than 5-6% of the energy mix by 2031-32 was formally accepted by the Indian government. Meanwhile, in August 2009, the Indian government changed this target to 25% for solar alone, half as photovoltaic (PV), but only provided it is aid-funded.[12] While the Solar Mission was launched in 2007, another Jawaharlal Nehru National Solar Mission was scheduled to be launched on 14 November.[13] Why this instability? Why have "sources of energy like sun and wind which are abundantly available in third world countries" (Stewart 1977: 60) been so dramatically retarded in a technologically competent society like India's? Is the right technology not available to decision-makers or are wrong choices being made by them?

Political-Technological Architecture of 'D'

Choice of technique – the D of research and development (R&D) – is now well-established as not a moment of decision, it is a long, embedded and contested political process in which institutions play paramount roles: the state as owner and controller ("participator") and regulator, the market where firms operate both individually in competition and collectively in representation (and regulation whenever the state fails to enforce its own rules), and a crucible of socially engineered or informal social institutions in which capitalist markets are embedded.

Solar energy has never been analysed like this in India and it is anyway very difficult to uncover the relations and tactics (sometimes called "policy technologies")[14] of the open and hidden politics of economic markets.[15] The first step is to understand the institutions, from the outcomes of which negotiations and power relations may be deduced. This is the step we make in this essay. Two analytical narratives are developed here: first a chronological institutional one, after which an attempt will be made to elucidate the politics of the technological-cum-policy system in terms of the logic of the process of D.

The topic and approach are littered with further problems. One is that while some policy institutions are clearly squaring up to the frontiers between state and market and are controlling and participating in D directly and others set the framework for private enterprise to compete, several of India's policy initiatives are "hybrids", simultaneously involving direct ownership and participation and also private sector regulation.[16] A second analytical problem is that the politics of D in renewable energy (RE) is accelerating its activity at the time of writing and solar energy components have entered the phase of their global "hog cycle" where they are in glut.[17] A third is that the politics of this least developed sector is being shaped by that of energy sources that would be threatened by its faster development – but the politics of coal, oil, gas, nuclear and hydro is out of the scope of this essay (Chatterjee 2009). In India, however, energy is substantially more state-controlled than in the United Kingdom (UK)/United States (US) so the process of decision-making in the public interest may be expected to be more powerful than the leverage of business. A fourth problem is that the scaled politics of markets is no longer national at its apex, but the international politics of energy is outside our remit here (Lakhotia 2009) except in one respect.

International Solar-Electric Politics

India supports the transfer of technology from the private sector of developed nations to the private sector of developing countries (DCs) on the ground that the relevant patents, cornered by private companies in ACs, constitute a barrier to technology transfer.[18] Already under the Rio Agreement of 1992, the need of DCs for environmentally sound technologies had been officially recognised – but not acted on (Correa 2000: 33). Already under Trade-Related Aspects of Intellectual Property Rights (TRIPS), to which India is compliant, while reverse engineering and compulsory licensing for export is prohibited, the protection of intellectual property (IP) is subject to the freedom to balance private interests with the public good and to the condition that technological innovations be promoted that are conducive to social and economic welfare. But this qualifier has not been tested in the energy sector. In 2009 the G-77 led by India and China called for a Multilateral Climate Change Technology Fund to buy IPRs, transfer them to DCs and also disseminate the associated knowhow (Singh 2009).

The proposal is opposed by the G-8 on the grounds that research bottlenecks are better relaxed by ensuring that property rights to research products can be protected rather than by shedding them; the latter could disincentivise the foreign direct investment (FDI) needed for the protracted "D" process of learning by doing. It involves "inappropriate" international bureaucrats in picking global winners (ibid). It goes almost without saying that transfers of ownership and competitive advantage are being resisted.

Political Institutions of State Participation in Solar Energy

In India, energy was nationalised before and during the Emergency in the 1970s. It is a state responsibility under the more or less formal direction of the central government. Like agriculture, energy is a "policy theme" scattered throughout many state bodies, and organised differently in different states. Each state also has a range of public corporations and development agencies concerned with energy and/or with renewable energy, though state electricity boards have no interests in off-grid technology. As in agriculture, direct participation is inextricably entangled with those of parametric regulation. The political architecture of solar energy has formidable coordination costs.

Bureaucratic Structure: The Department of Non-Conventional Energy Sources was established in 1976 to develop RE. From 1992, solar energy became the responsibility of the central government's MNRE and of power ministries at state level. While MNRE has been restricted to off-grid deployments, it has developed an internal complexity. Precociously early (1982), a set of solar energy centres were given the mandate under the MNRE to develop technology and to act as a link between state, market and "user organisations". Over the course of time this network has settled into a role evaluating and establishing standards for new technologies. Later responsibilities are discussed below.

Distribution: "Non-conventional" energy is also organised under the National Solar PV Energy Programme initiated in 1980. This has a set of highly decentralised "nodal" agencies in each state mandated with hybrid roles of participation and regulation and effectively protecting an infant industry at district level. In controlling local tenders for RE, they are vulnerable to capture by distributors with local monopolies so that the subsidy controlled by these agencies is not necessarily optimised (Rohra 2009).

Finance: Recently the Indian Renewable Energy Development Agency (IREDA), which had been established in 1987, but languished, was boosted (with Rs 17,000 crore) under the 11th Five-Year Plan to finance RE technology. Seventy per cent is destined for wind, while the remainder would nurture hydro, solar and biomass technologies. However, loans for technologies where costs are front-loaded (capital costs being up to 90% of total costs) have been actively disincentivised by regulation: interest rates exceed those of commercial sources (because the agency is forced to borrow from them) and a 25% deposit is needed to trigger loans. More recently, a special national incentive package scheme has been initiated for semi-conductors and thermal and PV cells – but suffering similar flaws. Rural banks are reluctant to loan to support solar technology. Investment is not coming from the fossil fuel sector. Under the Integrated Energy Policy of 2006, the Department of Science and Technology created technology incubators with a call for venture capital to invest specifically in renewable energy, energy efficiency and rural energy, but little is forthcoming.

Solar Installations and Gadgets: From 1995, a network of 268 "Aditya" solar shops had been created in upcountry towns to sell lamps and lanterns, etc, the licences for which have become a source of patronage and modest but widespread rent-seeking by individual retailers, non-governmental organisations (NGOs) and even manufacturers' associations. From 2002, private agents were given authority to disburse state subsidies for small-scale solar installations (solar water-heating, etc). So while knowledge of and demand for these technologies is still limited, the market for off-grid solar technology is now institutionally very rich.

Grid-Interactive Technology: Solar PV comes in wafers, thin film and concentrated forms. Concentrated solar power (CSP) technologies comprise parabolic troughs, linear fresnel, power towers, and dish/engines. Parabolic troughs are the commonest. The first three use the heat collected from the sun to power conventional Rankine steam cycles – and such steam cycle plants require cooling to function (to condense the steam). This cooling can be provided by water, air or a combination. CSP systems are normally situated in places that have many hours of direct sunlight and relatively scarce water. Supplying water from distant sources or purifying low quality water for CSP systems that use conventional water cooling can increase the costs or restrict the development of CSP. But using hybrid, i e, wet/dry (water and air) cooling systems, several large plants have been built worldwide which have traded off a 50% reduction in water consumption against only a 1% drop in annual electrical energy output or a 85% drop in water against a 3% drop in efficiency. Water is therefore thought not to be an insurmountable obstacle to solar energy in India.

Grid-interactive RE technology may also be developed for off-grid applications.

Like electricity generally, solar energy cannot escape being vulnerable to theft (often abetted by rent-seeking) and to physical losses. Decentralised, its installations are less easy to protect than conventional energy. It has been co-owned by the State Power Grid Corporations,[19] by the central MNRE and by the state electricity boards' transmission companies. The latter make such serious losses that they cannot be expected to bear further subsidies.

Only in 2008 did the MNRE establish *feed-in tariffs* for solar PV at Rs 15/kWh to a maximum of 50 MW capacity nationwide with the MNRE subsidising a difference between the states of up to Rs 11/kWh. Since the setting of tariffs for solar has to be initiated by the market institutions themselves, only a few states have tariffs.[20] Gujarat has responded by "betting on the strong" and developed 25-year purchasing contracts for larger solar plants (above 5 MW). The incentives given by individual states vary, West Bengal's being over 30% lower than those of Haryana and Rajasthan (Kamath 2009).

But the *capital subsidy* for grid-interactive RE has been capped for reasons of political expedience at an inadequate sum (Rs 50 crore) below which allocations do not require permission from the cabinet, ministries and Planning Commission. This is a powerful indicator of the low political status of the MNRE. Politicised to escape bureaucratic politics, this political constraint drives the impoverished Grid-Interactive Solar Policy target of 100 MW capacity (half as PV, half as thermal) within 10 years. But this is unlikely to be realised without the re-estimation of the states' subsidy. As happened with such a subsidy in the UK, the response from private entrepreneurs instantly overwhelmed the subsidy. Delays in its delivery introduce further incapacitating uncertainty to investment because of the impact of exchange rate fluctuations on the up-front capital costs on imported intermediate goods.

Grid Capacity: The electricity grid is a huge sunk cost whose life may be anything up to 50 years or more.[21] Though the scale of carbon reduction needed by 2050 means that by then energy solutions may be off-grid, the Indian state plans to expand the grid from 147 GW to 460 GW by 2030.[22]

Fiscal Regulation and Export Incentives: In 2007, the Indian government released another intervention that has elements of both participation and regulation. Its semi-conductor policy includes a special incentives package scheme (SIPS) consisting of tax holidays for production until 2010 together with a 20-25% subsidy and a reclassification of PV as an activity eligible for siting in special economic zones (SEZS). By 2008, $18 bn equivalent had been allocated for investment. And in Tamil Nadu, West Bengal, Maharashtra and Rajasthan, state governments are purchasing tracts of land and guaranteeing returns of 16% over 20-25 years for firms developing solar PV and thin film technology for export.[23]

Infrastructure is not confined to SEZS, but, learning from the public subsidy to the many successful IT clusters, state governments are creating the general infrastructure for technology parks and new industrial townships – roads, electricity and telecommunications, water, drains and sewerage, etc. These will demand electricity while RE is advocated to supply it.[24] The concept of the Solar Park, an industrial cluster for manufacturing solar technology, is also at pilot stage (Garud 2009). As well as water, land is crucial to application of technology: thin film needs much more land than crystalline technology and states are acquiring direct ownership of land.

Targets*:* An emerging politics of aspiration with far-reaching implications for enforcement is notably thin on the means of implementation. For instance, the 2004 Renewable Power Obligation – adopted in 12 of the states – has a non-mandatory and untimetabled "target" of 5% renewable energy. The National Solar Mission of 2007 (under the National Action Plan for Climate Change) laid a further stratum of institutional complexity to the policy "ecology" with the goals of developing 10 GW by 2020 (starting from just 2.1 MW in 2009 and expanding to 1,000 MV/year by 2017). And a draft law lies in the wings committing India to a 10% RE target by 2010 and a 20% one by 2020. The new August 2009 goal is 200 GW from solar by a new and non-comparable end date: 2040 (Rahman 2009). (Over) ambitious, time-bound targets have a long history in India and elsewhere, and certainly are not confined to the Millennium Development Goals (MDGS).

There is logic to the proliferation of hybrid institutions of state ownership and of state regulation – that of reaction to policy-induced price instability and risk-aversion by finance capital. The state's attempts to create, subsidise and incentivise learning rents have resulted in interstate competition and ever more elaborate niches for private rent-seeking activity.

Political Institutions of State Regulation

Regulation is tangled with state ownership and subsidy. Under the Central Act of 1999, a regulative commission sets tariffs, terms and conditions of trading, transmission and wheeling, standards and licences. Under the Electricity Act of 2003, it is the central state which has enabling authority for policy, tariffs, grid transmission standards and dispute resolution. The regulative framework lacks mandatory authority, so powers of discipline and enforcement are underdeveloped. While energy develops under a regulatory culture of state discretion, it is the Indian states which are responsible for the discretion involved in regulating private solar capital. So far under the new grid-interactive solar policy, it is Rajasthan, Gujarat, West Bengal, Tamil Nadu, Punjab and Haryana that have been provoked by private capital into initiating tariffs for solar energy and thus becoming eligible for preferential allocations for solar power technology from the MNRE. The policy incentivises plant above 5 MW and neglects rural electrification and off-grid applications.

Intellectual Property: The Patents Act of 1970 has been amended in 1999, 2002 and 2005 to ensure TRIPS compliance, protecting processes as well as products and to offer stringent IP protection and flexibility in implementation, including the issuing of compulsory licences. The latter, however, is not required if a product is manufactured primarily for export, which makes the policy tool irrelevant for solar PV. Should licences be granted under the act, the holder is required to "work the product" and maximise its local multipliers.[25] But the policy instrument is irrelevant in the solar energy sector not only for these reasons, but because *IP rights are not a barrier to development*. Licences for cell manufacture are accessible. Many wafering and other processes are established technologies and off-patent. IPRS are not a barrier to the expansion of capabilities in thin film-processing or the manufacture of crystalline silicon-based modules. These are being achieved through the purchase of licences or via joint ventures which secure the close interaction needed to protect "learning rents" (Mallett and Haum 2009: 10-12; Singh 2009: 39).

In 2008, first steps were made to protect IPS in Indian universities (after the US Bayh Dole Act)[26] in order to promote the commercialisation of technology. But this has been met with resentment by universities on the grounds that Indian research is basic and that public inventions should be in public ownership. Although the relation between India's state and university science is characterised as distant, it is far from being colonised by the interests of industry as is happening in the US/UK (Dickson 1988).

Social Status: Solar energy is part of a political culture which has given RE low priority and status and part of a social culture which has prevented – rather than facilitated – easy contacts between publicly-funded science and entrepreneurs. As a former MNRE secretary commented (Rohra 2009: 14): "The MNRE portfolio is given to a political ally who needs to be accommodated and to a bureaucrat who needs to be punished". Its current minister is Farooq Abdullah. The effectiveness of implementation depends on delicate balances of competence and power inside the ministries concerned. As another former MNRE bureaucrat explained (op cit, p 14):

> The siting of renewables in the Ministry of Power at the state level makes the success of solar depend in part on the relationship between the chief executive of the State Renewable Development Agency and the Minister of Power. In part it also depends on the initiative taken by the bureaucrat and his degree of conviction about solar energy. The continuous rotation of bureaucrats, often lacking technical knowledge is a hindrance. For example, in Uttar Pradesh (UP), India's most populous state, the chief of the state nodal (RE) agency was rotated seven times after the Bahujan Samaj Party assumed office in May 2007.

So patronage and rent-seeking (Wade 1985) severely qualify bureaucratic competence.

Solar Technology Package and the State

As with agriculture and food, so with energy in India, the state is diffusely proactive through an "institutional technology package": formally responsible for developing, coordinating, distributing, financing, for owning and for regulating what it does not own. But disincentives for D are built into the system of ownership, support, subsidy and regulation. The state created a technology package for the public sector, while the development of RE is shifting towards private capital as the prime mover. The state's comprehensive and complex institutional architecture is poorly resourced, strong on discretion and weak on coordination and enforcement. Solar is vulnerable to implementation delays. Despite this, power does not lie with the regulated so much as with risk-averse banks. And the banks' investment capacity is demonstrably feeble compared with state and market interests vested in FF and nuclear energy.[27] As is the case with Indian agriculture, this complexified institutional architecture, in which evolutionary reform gives rise to duplication and complexity without destroying redundant policy institutions, generates inconsistency in policy. It places obstacles in the way of bureaucratic entrepreneurship in the MNRE; restricts the development of RE policy for on-grid technologies, and rather than encouraging D, serves in practice to stall technical change at the stage of R.

Unlike comparative research on the UK (Harriss-White and Harriss 2007), at this stage we are not able to include the countervailing politics of energy sources which would be threatened, if RE had been allowed to thrive. But it is well-established that the ad hoc and party-politicised creation of the right to electricity has blossomed into a competitive politics of technology on two main fronts. First, rural energy has been deeply subsidised as a result of party-political competition.[28] Second, the state itself manages the set of financial support measures for coal, lignite, gas and hydro that were first placed in the public domain as late as 2008.[29] These dual burdens of cost have left Indian states sufficiently saturated with locked-in subsidy burdens that the resources required to subsidise RE are unforthcoming. It is not a matter of lack of "political will". Were resources forthcoming, such are the path-dependent interests created by this architectural complexity that it is hard to see how a bureaucratic system which has developed locked-in institutional complexity through piecemeal initiatives and reactions would be incrementally reformed, i e, *where* a step change in state support to state-owned solar energy would begin.

Political Institutions of Industrial Organisation for Solar D

It is laissez-faire that is planned and not only by the state, but also by capital. Markets do not only require a legal-regulative framework, they require infrastructure, organisations and institutions, most notably, sites, entrepreneurs, finance, supply chains and a framework for contracts in order to develop. As Frances Stewart argued in 1977, all such elements have their own independent technological requirements and lock-in. Solar energy is a set of technologies (crystalline, thin film, solar concentrators and non-silicon based products) each of which has its distinctive market organisation and capacity to develop and defend market shares.

Off-grid

The relation to the grid is used as a defining aspect of RE applications but polysilicon and crystalline applications may be used on- or off-grid. There is a set of products, however, which cannot be hooked to the grid. The market for solar inverter systems appliances: water heating, domestic lighting, street lights and cookers is organised by a combination of the niche interests of major oligopolists on the one hand,[30] and a mass of small specialist manufacturers and retailers, many in the informal economy, on the other. Their markets are so constrained that some major companies have taken to riding on local NGOs in unstable hybrid organisations in their attempts to penetrate "bottom of the pyramid" rural expenditure.

On-grid Technology

Manufacture: At present although India does not lack one of the basic raw materials, sand, the D of the several technologies capable of feeding grids requires technology transfer and the development of capabilities (see also Gupta 2009).

Silicon is manufactured into ingots in a highly energy-intensive process controlled by 30 companies worldwide, none of which had relocated to India at the time of writing.[31] Four of them, sited in Japan, Germany and the US, account for 60% of global production. The process was aggressively protected, and despite the 2009 US initiative for a "solar partnership with India", none of these companies currently licence equipment for production. However, as individual machines and components of the ingot, manufacturing process may be imported without a licence,[32] an innovative manufacturing company claimed to have sourced the components for manufacturing using a chemical vapour reactor.[33]

Ingots are then sliced into wafers (which is an open access technology), again until 2008-09 mostly in the EU and Japan.

Though India has yet to develop silicon wafering capabilities or the ability to produce feedstock to the necessary high standards of purity, two domestic applications for wafering have been filed.[34] Up to 12 Indian firms have arranged to buy or license equipment and processes for silicon production from foreign companies.[35]

Wafers are then used to make semi-conducting cells (a series of small processes out of patent) which are assembled into modules.[36]

The wafer sector consists of three large state enterprises,[37] nine solar cell firms all experienced in chemicals manufacture (dominated by two)[38] – plus 18 PV module manufacturers. They are surrounded by small specialised firms which manufacture bespoke applications. In the case of wafer and cell manufacture, the vast majority of these enterprises have licensing agreements with the US and EU companies. Internationally, the manufacture of PV is currently at the glut point of an investment cycle (Kamath 2009), yet domestically demand is insufficient for either scale economies or vertical process-integration.[39]

Thin film uses an entirely different form of silica – amorphous (aSi) – coated onto a backing such as glass. Japanese companies lead in this sector India-wide, a handful of firms have entered this sector.[40]

Solar is not simply a peculiarly adult, infant industry, but an import- and export-led one. The silicon wafers for solar cells have to be imported, while some 70% of solar thermal and PV modules is currently exported to Europe despite the enormous potential domestic demand. A third component of the private sector's organisation lies latent at present. If it is developed, on-grid solar power supply is expected to be dominated by multinational companies (MNCs) and Indian corporates, rather than state corporations.[41]

Finance: Finance capital has made a lacklustre response to the new technologies and markets. The Indian banking system has proved reluctant to invest in relatively small individual projects[42] with high transactions costs and risks in a sector, power, which has been discredited. One plant alone is being funded through private equity and the capital markets.[43] Commercial development risks are being supported by a handful of Asian-regional and national public financial agencies.[44] Their investments increased rapidly from $32.2 bn in 2004 to 148 bn in 2007. Since India has yet to develop a long-term debt market, the long-term risks of D and "R for D" have to be borne by equity. A third of the $3.3 bn of private equity and venture capital invested in RE has gone to solar energy, most in the form of assets finance supplemented by mergers and acquisitions. A small but influential network of foreign donors, international and local banks[45] are engaged in ad hoc promotional projects. For example, since 1995 the International Finance Corporation (IFC) has invested in four private equity initiatives. The United Nations Environment Programme (UNEP) collaborates with Canara Bank and Syndicate Bank to subsidise interest on solar loans and a coalition of private donors have supplied some $11 m for experiments in rural solar business models.[46] *Indian bank finance for solar energy is therefore channelled to state-owned enterprises with secure state-guaranteed returns.*

For the same reasons access to retail finance for investments by final consumers is so restricted that it has had to be developed by NGOs, NGO-business hybrids and foreign aid donors (Kay 2008). UNEP has provided loans for 18,000 households to gain access to off-grid solar; the World Bank has dedicated $10 m of a $26 m RE loan to solar and the Department for International Development (DFID) has invested in off-grid solar lighting for women, dalits and adivasis in remote villages in Andhra Pradesh (Rohra 2009).

While a mass of new small companies has been allowed to enter, the firms capable of D on a national scale – national capital and MNCs from Germany, Norway and the US – are waiting in the wings.

Politics of Collective Action for Solar Energy

In the UK, collective action for and against RE takes the form of a combative marketplace of lobbies that have penetrated most stages of the policy process, but in India, the type of collective political action currently required is still a "prior" to the development of direct lobbying. It takes the form of alliance-construction. Some of the *institutional hybrids* that result evolved early on but have mediocre track records. They consist of interests mobilised for "public education". A well-informed policy elite is necessary for the political leverage needed to release limiting constraints on the D of the range of solar technologies. The state is appealed to as the authoritative decision taker. Despite appearances, hybrid NGO-lobbies are not civil society NGOs because they work in the interests of specific industries. Hybrids include the Clinton Global Initiative which advocates RE purchase by Indian planned industrial townships and new towns and The Energy and Resources Institute's (TERI) campaign with Tata BP to promote the purchase of 450 m solar lanterns (of which only 2,600 have yet been sold) in off-grid villages with co-payments to maintenance entrepreneurs.

Trade Associations: Established in 1976, the Solar Energy Society of India was designed to encourage public sector R&D and public information. Much more recently, a trade association, the Semi-Conductor Equipment and Materials International (SEMI), has established an Indian advisory council to reduce the social distance between higher education research and business (SEMI 2009: 12). It also collaborates with the Indian Semi-conductor Association to create public events ("conferences") to increase public knowledge and gain lobbying power.

In marked contrast, while it is Japan which is developing cutting edge solar technology, it was Obama's first trade mission in 2009 that targeted India for a "solar energy partnership" (Menon 2009).

India has well-organised and powerful *industrial lobbies*: the Federation of Indian Chambers of Commerce and Industry (FICCI) with a centre of gravity in commerce-based business; the Associated Chambers of Commerce and Industry of India (ASSOCHAM) tending towards export industries and big regional chambers of commerce; Confederation of Indian Industry (CII) representing engineering and manufacturing and National Association of Software and Service Companies (NASSCOM) representing the software industries and services.[47] CII's collaborative "white paper" with the government of India's own central electricity authority – on energy strategy for the 11th Five-Year Plan, published in 2007, did not mention RE.[48] FICCI collaborates with the Ministry of the Environment and Forests on two conferences in late 2009, one on investment for the Clean Development Mechanism and one (also with the United Nations Department of Economics and Social Affairs (UNDESA)) on technology development and transfer – in which energy has the highest priority. ASSOCHAM hosted a renewable energy conference in mid-2009, where solar had pride of place. Late in 2008, NASSCOM started a "green IT initiative" for services which are energy-intensive but it focuses on energy waste and efficiency rather than energy sources. For these lobbies, RE and solar at present are a field of information rather than of investment and politically these lobbies do not speak as one voice.

What about the collective action of *organised labour*? Some 1,00,000 jobs for skilled labour were reckoned to be needed for India to fulfil its 2007 RE target by 2020 and many more will be necessary for the new 2009 target. The MNRE is designing curricula for them with the Indian Institutes of Technology (IITs). The number of "blue collar" jobs needed has not been calculated. But the idea that India's poorly educated labour force can supply this labour does not match practice elsewhere – let alone that it be organised or that organised labour campaign for it.

Trade unions represent only 3% of the Indian workforce. Most are organised around firms or are party politicised – taking their agenda from party politics and not representing a distinctive class perspective on RE. Unions are also divided between sectional interests of public versus private labour forces; and (worldwide) those representing existing sources of energy are hostile to new technologies. Interviewed at the March 2009 World Social Forum, the leader of India's New Trades Union Initiative (NTUI) which is independent of party politics admitted that "the environment" had no impact on trade union politics or vice versa, not for lack of information but due to national party political indifference.[49] The contribution of the Indian working class to climate change was not a topic to be shirked but neither was that of military aggression and the defence industries. Clean public transport and energy efficiency would be campaigning priorities for the NTUI.[50] So not solar energy.

In Sum: Collective action is as yet a contingent political element and the sets of interests have no authoritative apex body to represent RE or solar. They are politically uncoalesced and in the process of forming consensus.

Socially- Embedded Solar Politics of Civil Society

RE is *not* well-socially-embedded either. It also has low status and priority among intellectuals. "Power engineers tend to look at renewables somewhat disparagingly", commented a highly placed technocrat. All commodities have "quiddity" – distinctive combinations of physical characteristics and social and symbolic meanings which often have implications for market structure and behaviour (Harriss-White 2003, Chapter 8). The political and "social" status of RE is low. Specialist technical education for the skilled labour force is underdeveloped and the diffusion of knowledge about RE and solar is slow. Here we will examine the roles of science, NGOs and think tanks, and the media.

Science: Both science and scientific policymaking are not just technical wings of the state but are socially constructed and embedded.[51] Private companies in 10 advanced countries currently account for 80% of global research in solar energy and for 90% of international royalties and technology fees. Forty-two per cent of the solar patents registered between 1998 and 2003 were in Japan alone. Indian RE research, not in private control, is not at the cutting edge, neither has it underwritten much experimentation, nor has it played a role in educating society at large.[52] It is characterised by "low risk", "inward orientation" and "mistrust of the private sector".[53] The MNRE is disabled by a research budget of under $100 m to tide it from 2007-12. Amid this under-performance, India nevertheless produces the largest absolute number of scientists and engineers worldwide. As yet, however, there is no certification programme for solar engineering. IITs, IISCs and Jawaharlal Nehru Technology University all have departments of solar energy, but only 12 are research-active. Some of these are able to produce pilot technologies, but as with science more generally, there is little interaction between the labs and the business economy. Indian joint ventures are starting to fill the domestic research gap: Moser Baer is investing $3.2 bn between 2009 and 2012. Subject to funding, certain private companies in India would even go so far as to entertain plans to pilot research for D in universities in the US and Australia.[54] Only one Indian firm has developed complete in-house R&D capacity (in thin film).[55]

So India has had research institutions in place for two decades, but with little impact either on solar energy D or on society. India still claims to aspire to develop "truly disruptive innovations" and "new paradigms for solar cell design" (prime minister's Council on Climate Change, June 2008: 22). Many research frontiers are being colonised outside India, while research for commercial development needs to be developed at home: for example, crystalline cells with multiple layers instead of two; tandem junctions in thin film; improved efficiency and techniques in silicon production and wafer slicing; alternatives to silicon (cadmium and copper compounds) in thin film and increases in both physical efficiency and cell life.[56]

Environmental NGOs/New Social Movements: In the UK, organised civil society wields an environmental reasoning (and polemic) but without the material clout of the industrial lobbies. It has had a signal success in forcing the issue of climate change up the political agenda only to be rejected for its "dogma" by the political elite. In India, the environmental movement is a newcomer to a family of new social movements[57] which has been dominated by the aspirations of women, dalits, farmers and the struggles of ethnic groups. Absorbed with problems of social forestry and forest protection (against encroachment and displacement by mining and infrastructure) and with an opposition to genetically modified (GM) seeds on the one hand, and mobilised against urban air pollution, urban toxic wastes and their impact on the other, there has been very little role for energy in general, and solar in particular, in India's environmental movement.

Think Tanks: While bearing a family resemblance to NGOs and civil society organisations, think tanks are hardly ever disinterested research bodies. Often funded by industries and disguised elements of the lobbying industry, they are offshoots of the field of accumulation – which affects what they cannot "think".[58] Increasingly these hybrids may be subcontracted agencies of the state. Some are large and globally influential. TERI is paradigmatic, headed by the Nobel Laureate, Rajendra Pachauri. TERI evolved from being a Tata-funded institute to a multi-sourced one. Working with 800 staff on "every aspect of sustainable development", it produced some 218 publications in 2007-08 of which four were explicitly on solar energy (TERI 2009: 136-49, 164). It conducts feasibility research on solar for the private sector and is developing the idea of solar parks (Garud 2009). The Centre for Science and Environment, headed by Sunita Narain, researches and campaigns on air pollution, industrial environments, natural resource management and education. Of its 34 publications, none is on solar energy. The World Institute of Sustainable Energy, headed by G M Pillai (adviser to the government of India and chief of RE for the government of Maharashtra) collaborates with the MNRE on research and training and with wind turbine manufactures to expose the extent of FF subsidies worldwide. It has a Centre for Solar Energy, working with industry and government to develop public and private capacity for solar energy. One of its four major publications is a manual for solar entrepreneurs. So solar energy has a small niche in India's environmental think tanks.

Print Media*:* The print media, which is largely privately owned, is the source of information on aspects of climate change for 70% of Indians. In an exhaustive content analysis of 21st century media coverage, Billett (2009) finds that the print media has developed a "post-colonial binary" narrative, focusing on threats, attributing cause to "advanced countries" and demanding they lead in both mitigation and compensation to "developing countries" for their adaptive responses. This framing avoids the complicity of India's upper income deciles in the high carbon emissions that damage those in the lowest deciles. Solar energy is regarded more as a means of adaptation than mitigation.

In India, while environmental causes are many and various, civil society is generally ignorant about solar energy, and despite the very recent endorsement from the prime minister, it is left to a small number of active institutions to strive to establish its social legitimacy.

Conclusions

In this essay we have tested an approach to the understanding of technology and development which situates technical change in the institutions and politics of markets, embedded in turn in those of the state and civil society. The results will be discussed in three sections: the light shed on the theorising of technological change; the analytical substance of our work; and its implications for policy.

Theoretical and Methodological Conclusions: It has long been understood as misguided to theorise technical change as an individual act of choice. It is a process of decisions in a technological system or package. While the parsimony of the institutional tool kit of the conventional "innovations systems" approach may appeal (consisting as it does of actors, networks and institutions), the case of solar in India shows the importance of an expanded and concrete list, in particular "infrastructure for communications, banking and insurance; scientific and engineering capabilities; legal and administrative institutions (particularly, IPRs and licences), managerial capacities and an appropriately skilled labour force" (Stewart 1977). "Banking" needs to include financial aid transfer institutions. These are *general* requirements often missing from the analysis of the existing or theoretically desirable technological package for a specific product.

The example of solar energy supports the justification for a political approach to the analysis of technical change and its economics. In using the politics of markets as its analytical framework, this evaluation of stalled and inappropriately slow technological change introduces a political dynamic to the idea of the technological system. Understanding this dynamic requires expanding the concept of the "political" into the sphere of the economic and conceiving the choice of technique as an element in the development of capitalist markets. Furthermore, policy-making is not confined to the state. Capital must expand and in so doing it strategises to introduce new technology, reduce labour costs, transform state-protected sectors into fields of profit,[59] and persuade the state to support a process which often threatens itself. The state must then select those risks it will bear. Key institutions are those of: state control/"participation" and also the state-regulation which facilitates such change; the (self- and state-regulated) organisation of markets which affects resistance to disruptive change; the collective action which is a necessary prior to market competition; and the wider social forces in which capitalist markets are always embedded.[60] To understand these institutions and the politics of the interests they reflect information which is voluminous and elusive, much not publicly available, some competitively secret. A first scratch at the surface involves laying out its "architecture": the institutional elements through which the political dynamic is construed. This is mainly what has been done here and one of its theoretical interests is the prevalence of institutional hybridity. But the significance of this theoretical building block for development theory will only be realised under two further difficult conditions. First, the political relations and political agency (also called "policy tactics") between the architectural elements needs research and public understanding. Second, development itself has to be reconceived as a process of extraction, use and *restitution* of social useful forms of material and energy under political and social relations, which are appropriate for generalised human development.

Analytical Conclusions: In considering inappropriate or inappropriately delayed technology transfers in "Technology and Underdevelopment", Frances Stewart asked whether the right technology is not available or whether the wrong choices are being made (Stewart 1977). To which the answers here are "no but" and "yes but". The right technology is available and is not obstructed by patent law so much as by the structure of domestic subsidies, the reluctance of banks, price instabilities and the coordination failures of the technological package built to facilitate it. The wrong choices are locked-in to India's energy system through the non-transparent, lifecycle and lifetime physical and financial requirements of FF technologies competing for public support and infrastructure. India is not unusual in this respect. It is unusual in its public institutional support to renewable energy.

Initiated precociously early, the subsequent development of the solar technological package has marginalised and disincentivised solar. In this conclusion, the paradox of precocity and failure needs explaining by the politics of markets in a sector – energy – still dominated by state-ownership, and much more comprehensively, state-regulated, for development in the public interest than is the food sector.

State Institutions and Politics: States can work without markets but markets cannot work without states – even if in accommodating private and public interests states may create techno-political systems which retard or prevent the development of markets. In RE, the Indian state created the publicly-owned and controlled institutions to develop RE but did not endow them with power to challenge incumbent technology. Even though no established energy institutions have been threatened, RE is treated as though it were a threat. The state is currently incapacitated from operating in the public interest which would prioritise the rapid development of solar. While the state is active in the creation of a technological package for private capital, power relations between institutions express the deep reluctance to redefine the public good as the good of private solar business. Yet, despite the prime minister's discursive encouragement, and in spite of continual expansion of solar goals alongside receding future end-dates for these goals, public institutions are not fast-tracking solar.

India's regulative institutions operate a two-track approach – manifest in both state participation and regulation (and visible in other areas of policy such as food). They encourage the domestic duplication/copying/reverse engineering of innovations made elsewhere on the one hand, and advocate the (free) transfer of technologies internationally, funded by ACs, on the other (Singh 2009: 11; Rahman 2009). While the 2006 energy policy cannot be faulted for political coherence, when the detail necessary for action is examined, this dual project is found to result in domestic technology policy and institutions which are operationally incoherent at different political scales. While the international politics of state participation supports the transfer of ownership of IPRs, national politics supports licensing and import. The ease of import exacerbates disincentives for the domestic R being encouraged in the IIScs. While R is designed to be in state hands it is now being de facto privatised. D is a field of competition between an array of public and private agents operating at scales from the district to the national, and all thoroughly marginalised by those for conventional energy. Some regulative policy is designed to be incoherent, with states competing to negotiate feed-in tariffs but only when business demands them.

There is a social and cultural distance between state, science and market institutions and between the status of RE and that of conventional energy that cannot be fixed by institutional design alone.

Market Institutions and Politics: Though it protects its own solar industry, the US has not been able to prevent RE being developed elsewhere, notably in Germany and Japan,[61] while the rest of the OECD dozed. AC technology is not prevented from flowing to a technologically capable country like India – indeed, the Obama administration and the Clinton Global Initiative are now selectively encouraging business partnerships – but at a price. In the face of incoherent policies for solar, and with the sector dominated by state enterprises and an oligopoly, but strewn with small specialist firms, India is developing technology for export which it actually needs domestically.[62] Licences are not a constraint, but their cost rations them to the apex of the RE sector and reinforces inequality in the sector's organisation. The disciplining of regulation is suffused with discretion. Informal contacts enable India to burrow under international regulative protection and find ways of acquiring the most protected element – process technology – in the face of the indifference of its own finance capital. Despite a well-developed banking sector and a huge corps of innovative engineers, India's markets for money and labour do not support the sector. Industrial lobbies are at the stage of informing rather than representing the interests of manufacturers – let alone those of labour. Trade associations and hybrid institutions of collective action struggle to establish the legitimacy of solar energy. The sector is poorly recognised – and not backed by – civil society. Neither science nor the media have developed public education; environmental movements have many other objectives than the promotion of solar and RE is a niche specialism in environmental thank tanks.

It is no good calling for political *will* – this essay has cut an "archaeological section" through political will at work – there is little political *interest*. Yet, the global response to climate change requires a radical shift in technology and this cannot be achieved with the technological system constructed by political interests analysed here. In India, one of the most strategically important nations in the climate change response, the existing institutional architecture for solar energy, while constantly evolving, moves in directions hostile to the "new technological paradigms" to the development of which the Indian government itself is discursively committed. *Without institutional destruction*, an "alternative political economy" (Stewart 1977) cannot be engineered through an incremental change to a technological system that has developed internal structural inconsistencies through incremental change. Again, India is not unique in this. A similar process is currently "complexifying" the reform to the incrementally evolved publicly-funded international agricultural research system under the Consultative Group on International Agricultural Research (CGIAR).

Policy-Relevant Findings

First, while all eyes are on India's geopolitical strategy for Copenhagen, this research suggests that India's *international political initiatives* may be misconceived with respect to technology transfer. IPRs are clearly no barrier to the expansion of advanced capabilities in solar. Special new institutions or aid based on IPRs as a tool for technology transfer are not necessary. Neither is a specially skilled internationally mobile labour force for skills transfer to India. The most generous interpretation of the contradictory regulative framework in which India calls for an international funding body to remove a barrier that does not exist is then that it is acting as a trustee for the interests of less technologically proficient DCs.[63] Alternatively, India may be looking far beyond imitative adaption to a time when IPRs in new thin film technology may be protected by their developers in a manner radically different from their current licensing practice. But that is not what is said. The international attention to IPRs is distracting attention from more serious policy problems.

Second – and prime among these problems and well outside the public framing of the D of RE – it is in the immediate public interest in this era of apparently liberalised competition to know the degree of *underestimation (and the pressures on public finance) of the cost to society of conventional fossil fuel-base, hydro- and nuclear power.* This is a *general* policy implication for D drawn from literature[64] not confined to India. Levelling the playing field would either mean addressing the costs of the negative externalities of FF and nuclear energy, removing their subsidies and support *and/or* providing new forms of energy, in particular, solar, with comparable or greater ones as befits very socially valuable infant industries. Not to do so breaks with established historical practice worldwide. It is an extraordinary anomaly in the global response to climate change.

Third, while this essay has revealed the combinations of the institutional complexity and low status of solar energy's technological package as formidable obstacles to its development, *the limiting constraint on solar energy is not land, water or raw materials, it is financial* – particularly for commercial pilot projects. Like renewables, generally, solar energy has heavy up-front capital costs and relatively low running costs. While the costs of on-grid technology have been declining worldwide and those of many off-grid applications are profitable without subsidy, India's banks are so far from entrepreneurial for the RE sector, interest on loans is so high, that finance is the preserve of public banks for public sector initiatives or substituted for by international development banks and aid agencies. This surely has to be changed but change depends on the second policy implication outlined above. Obvious priorities are off-grid solar technology and loans to grid-interactive solar energy developers – whether private or public.

In Conclusion: An observation that is non-economic, non-technological and non-policy-oriented: Technical change in solar energy is coming from a process of entrepreneurial "acts of witness" rewarded by low rates of profit. Of course, the need for subsidies, infrastructure, institutions and sites speaks volumes about the power of the subsidy on FF and nuclear energy to prevent the development of solar. But the fragile institutional life of solar energy has been not so much a process of technical choice, but rather a painfully drawn-out *process of resistance* by entrepreneurs in private and public sectors who are marginalised within their own elites. This conclusion is well-supported by the sheaves of policy statements – "the official transcripts" – in which plans for solar are pushed to the margins.[65] *Resistance* has been theorised as a property of subaltern classes, expressed both openly and through "hidden transcripts" – the private "offstage" dialogue about practices and purposes (Scott 1990). While a first attempt to describe the complex "open transcript" has been made here, the hidden transcript of a subset of the capitalist elite is an unorthodox metaphor in need of further research. But that the D of solar so far has been an act of elite resistance is not so indulgent a conclusion when faced with mass denial about coal and lignite as other than the natural order, as other than the arrangement making "pro-poor development" possible, and "cleaner coal" as other than the paramount technological imperative. These are all carefully constructed "foregone conclusions" and "policy imperatives" (Schaffer 1984).

Multiple "institutional failures" in India's technological/innovation system for RE have yet to be tested as reflecting the success of the politics of procrastination and sabotage by the established energy sectors.[66] Here they are shown to be the result of a powerful combination of institutional complexity, low status and lack of finance. However, this essay has also shown how the political architecture and interests are changing and it would be a mark of greatly needed progress if its analysis were *not* to stand the test of time.

NOTES

1 See Billett's content analysis of Indian media, 2009. The UK/EU's average is nine tonnes; India's currently is 1.2 tonnes (UNDP 2007).

2 The UK is a laggard (NFU 2005).

3 Toe = tonnes of oil equivalent.

4 Installed generation is planned to expand from 160 to 800 GW by 2031-32. See the government of India's National Action Plan on Climate Change, government of India, prime minister's council on climate change retrieved April 2009 http://pmindia.nic.in/climate_change.htm 2008.

5 GOI, *Integrated Energy Policy*, Ministry of Power, New Delhi, 2006.

6 India plans to add 640 GW and the upper-end estimated potential of solar energy is estimated at 600 GW, according to the Indian Renewable Energy Development Agency, not to mention wind, upgraded biomass and small hydro which exceed 100 GW (Brar et al 2008)

7 Kammen et al (2004); In India: 25-40 direct jobs per MW (10 in production, 33 in installation, 3-4 in systems wholesaling and supply and 1-2 in research (Weiss 2009).

8 WISE (2008). Large hydro is also heavily subsidised. Externalities have never been costed.

9 While liberalisation is conventionally dated from 1991, C Dasgupta's careful research sees liberalisation as a process of institutional change whose politics were active from the 1960s (2007).

10 1.2 GW out of a total generating capacity of 160 GW in 2008 (Brar et al 2008).

11 Government of India 2008, *Eleventh Five-Year Plan,* Planning Commission, New Delhi.

12 And the end date receded to 2040, Rahman (2009). This demand for $20 bn of dedicated bilateral aid contradicts India's current Copenhagen position for a multilateral technology fund – currently opposed by the G-8. See ibid, pp 17-18.

13 Manmohan Singh 2009: Independence day speech.

14 Fernandez (2008) on policy technologies explaining why policies to empower poor, tribal women have the opposite effect to that "intended"; see Szlezak (2006) on the commodification of Argentinian pensions for a fine example of hidden politics and for the care needed in field research.

15 The evidence used here is from Rohra (2009); and Singh (2009). Due to the extreme paucity of academic research on solar energy in India, both Rohra and Singh conducted telephone interviews with key stakeholders (Rohra 14; Singh 7). Rohra relied on reports published by state and central governments, industry associations, advisory and consultancy firms, NGOs and the print media. Singh did likewise and was also given a pre-publication access to research by Alexandra Mallett and Ruediger Haum at Sussex University on technology transfer in Indian solar PV (2009); see also Ockwell (2008).

16 Of course, the disjuncture between "policy as science" (Dickson 1988) and the "characteristic complexity, messiness and historical specificity of policy processes" (Greenhalgh 2008, p xiii) is far from being confined to India. It is observed everywhere policy has been examined in detail and has been the object of weighty research in science and technology studies (Latour 1987 and Jasanoff 1995) and the anthropology of policy (see the review in Greenhalgh op cit Preface and Chapter 1).

17 In 2007 worldwide, polysilicon increased by 30%, wafer manufacturing capacity 73% and PV cell production 55% (Majumdar 2009; Rahman 2009; Kamath 2009) as a result of which polysilican prices have dropped by 60% in 2008-09. There has been a massive expansion in China (Indian Industry Executives, Pers Comm to Singh, July-August 2009).

18 *National Action Plan on Climate Change*, GoI, 2008, p 2; G-77 and China, 2008, p 3; GoI, government of India submission to UNFCCC on Technology Transfer Mechanism 17 October 2008, retrieved December 2008 from http://unfccc.int/files/kyoto_protocol/applications/pdf/indiatechtransfer171008.pdf

19 West Bengal has two solar plants and Gujarat, Maharashtra, Punjab and Haryana are following

suit. By the end of 2010, central and state governments are expected to have 1,000 MWS of generating capacity (Industry Executive, Pers Comm to Singh, August 2009).

20 GoI policy formally favours a feed-in tariff, after the positive experience in Germany and the lacklustre experience of a renewables obligation in the UK. However, given the need for a concerted phasing of feed-in tariffs and the current unsystematised state of the decentralised tariff-creating processes, there may well be a case for a *mandatory* renewables purchase obligation at state level to force (rather than to incentivise) the process (G M Pillai, Pers Comm, cited in Rohra 2009).

21 Stewart makes the point that the life expectation of infrastructure is a culturally specific convention – half in the US what it is used for estimates in the UK (1977, p 101).

22 The grid expansion plan is seriously out of sync with plans for electricity generation, GoI (2006).

23 SEZ research shows that domestic supply and employment multipliers are often limited and that tax exemptions and the costs and path-dependence of infrastructure create learning rents that are hard politically to phase out (French 2008).

24 See the Clinton Global Initiative discussed under "collective action" here.

25 Singh (2009), pp 19-20 citing personal communication with Basheer, 30 May 2009. See also Basheer and Primi (2009).

26 The Protection and Utilisation of Publicly Funded Intellectual Property Bill, 2008, is named after its introducers.

27 WISE (2008); Lakhotia (2009). In 2009 Shyam Saran, the Indian prime minister's special envoy for climate change went on record saying "nuclear energy is renewable energy *par excellence*" (Menon 2009). In practice, its source, uranium, is being rapidly depleted and is non-renewable.

28 See for example, Janakarajan (2004).

29 WISE (2008). Public sector support measures and subsidies to nuclear energy are not in the public domain.

30 Tata BP; Selco; Orb Energy (Rohra 2009). BP has experimented with NGOs (see Kay 2008, for improved stoves and a review of other renewable energy applications).

31 From 2008 to 2009, this has increased from 12 firms, most of the expansion being in China with small numbers of entrants in Russia, Korea and Europe.

32 Even though the development of the capability to import required the use of consultants to the global oligopoly (Singh 2009).

33 A substantial industrial group (Singh op cit). It has been stalled by lack of finance and the fall in silicon prices.

34 Maharishi Solar and Metchem Silica (Singh 2009, p 37; citing Pers Comm with industry executives, in April 2009).

35 None have gone into production (SemIndia executive, Pers Comm to Singh, April 2009).

36 Gupta (2009), gives a useful graphic account of the technologies involved at this stage which include parabolic troughs and Fresnel mirrors.

37 Bharat Heavy Electricals; Bharat Electronics and Rajasthan Electronic Instruments (Rohra 2009).

38 Tata BP; Moser Baer (Rohra 2009).

39 An industry executive estimated that individual firms need to expand from 125 MW to 1 GW before scale economies accrue. Likewise thin film must reach 500-600 MW before vertically integrating on-site gas production (which cuts the costs of gas by 75%) (Pers Comm to Singh, 1 August 2009).

40 They include Moser Baer PV; Tata BPO and High Hind Vac. The latter is alone in manufacturing using their own processes and in developing research capacity to increase the efficiency of thin film. Moser are also doing research in thin film but are not as far developed (CEOs, Pers Comm to Singh, July 2009).

41 Reliance; Moser Baer; Signet Solar; AES Solar; Suzlon; Larsen and Toubro; Tata Power (Rohra 2009).

42 Rs 15-20 crore.

43 Mumbai-based banker, personal communication to Singh, July 2009.

44 Government of India Future Fund; Global Environment Fund; South Asian Environment Fund; Infrastructure Development Finance Company (IDFC) and the Sun Group (Rohra 2009).

45 DFID; the International Bank for Reconstruction and Development (IBRD)/International Finance Corporation; UNEP; Global Environment Facility; Asian Development Bank (ADB) (Rohra 2009).

46 Shell Solar; SELCO; SREI International Finance; Shri Shakti Alternative Energy (Rohra 2009).

47 FICCI declares a membership of 1,500 corporates and 500 Chambers of Commerce; ASSOCHAM has "over two lakh" companies and professionals; CII, 7,800 organisations and NASSCOM, 1,300 (see respective web sites and latest annual reports).

48 CII (2007), see especially pp 34-42.

49 Progressive trade union activists are fully extended in defence against attacks on labour security and work rights, retrenchment, displacement, outsourcing, on outreach to women, the informal economy and on exposing and countering caste/ethnic discrimination (www.LabourFile.org). The Indian Labour Conference of 2009 did not consider climate change or energy.

50 Gautam Mody on www.youtube.com/watch?v=NWtLvpHHTmc accessed on 26 August 2009.

51 See the review in Greenhalgh (2008).

52 In general, India spends just a third of the average GDP spent by DCs on R and D, 0.8% as compared with only 2% (government of India, *Government of India Submission to UNFCCC on Technology Transfer Mechanism,* 17 October 2008, retrieved December 2008 from http://unfccc.int/files/kyoto_protocol/applications/pdf/indiatechtransfer171008.pdf, p 165).

53 According to a senior bureaucrat in the MNRE (Rohra 2009).

54 Industry executive, personal communication to Singh, August 2009.

55 High Hind Vac, a research capacity supported at one stage by the Kolkata Indian Institute of Science. Other firms such as Moser Baer are building research capacity incrementally. The MNRE plans to match R&D costs of private companies. But R funds are not tracked by the MNRE and the scope of D has not been officially defined.

56 Average efficiencies are about 17% for crystalline cells, while theoretical limits are 24%.

57 Omvedt (1993) distinguishes them from "old" social struggles on the grounds of their being anti-systemic, not confined to the working class, mobilising groups ignored by Indian Marxists or problems of exploitation inadequately understood by Marxist movements.

58 The Indian think tanks researched here do not publish the sources of their funds on the internet.

59 Commodification is not confined to the privatisation of public sector activity, the policy process, bureaucratic activity or public science and technology development. It extends to common property resources, nature, the domestic sphere, the body and the building blocks of life itself. See Leys (2007).

60 In India's dominant informal economy these form a social structure which tends to stabilise accumulation (see Harriss-White 2003).

61 In the OECD as a whole including the US R and D for RE grew between 1978 and 1983 but atrophied thereafter. In the UK it declined in real terms between 1994 and 2003. Over the OECD, public funding for socially discredited civil nuclear energy is currently 20 times greater (Jacobsson and Johnson 2000; Schneider et al 2008).

62 The oft used comparator of pharmaceuticals – which developed capabilities through reverse engineering in the era before India's accession to the WTO such that post TRIPS its apex could develop indigenous R and D (Kale and Little 2007) – is inappropriate on two grounds (1) the post-TRIPs regulative context, and (2) limited patent constraints.

63 The phrase is Barton's (2007), see Singh (2009).

64 WISE (2008), scoured the literature worldwide finding limited evidence, which nevertheless indicated extensive subsidies on energy from fossil fuel.

65 Official transcripts of the government of India include on Copenhagen; Integrated Energy Policy 2006; National Action Plan on Climate Change *Government of India Submission to UNFCCC on Technology Transfer Mechanism* 17th October 2008, retrieved December 2008 from http://unfccc.int/files/kyoto_protocol/applications/pdf/indiatechtransfer171008.pdf

66 See Lakhotia (2009), on the business interests benefitting from India's nuclear deal though he was unable to discover whether they actively thwart RE. See also Chatterjee (2009), on coal politics.

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