REVISITING '*TECHNOLOGY AND UNDERDEVELOPMENT'*: CLIMATE CHANGE, POLITICS AND THE 'D' OF SOLAR ENERGY TECHNOLOGY IN CONTEMPORARY INDIA

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Abstract

This paper explores the political economy of technical transfer and development. In her far-sighted and far-reaching book, 'Technology and Underdevelopment' Frances Stewart examined technological transfers which were inappropriate for their new factor endowments. She analysed the implications of technological dependence for income distribution and employment in developing countries. On her retirement, this tribute to her work is in two parts. First, we revisit 'Technology and Underdevelopment' (TandU) in the light of subsequent research on – and criticism of - innovation systems. We make a case for embedding the analysis of technological change in the politics of markets. Second, we develop the first stage of a political analysis of a technological system to explain the retarded development of apparently appropriate solar energy technology in India and to evaluate the weights of explanatory factors emphasised in TandU and those of later schools.

technological systems, politics of markets, solar energy, India }

'Technology is a principle of social order.'[2]

'We are at sea without navigation instruments'[3]

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[2] Peter Drucker, cited in Thompson, 1988

[3] Sir Crispin Tickell, the distinguished retired civil servant who persuaded Margaret Thatcher when PM of the significance of global warming, at the LSE, June 5th, 2009

In a far-sighted and far-reaching book, published in 1977, Frances Stewart[4] explored technological transfers which were inappropriate for their new factor endowments. She analysed the implications of technological dependence for income distribution and employment in developing countries. In this essay, which is in two related parts, first we revisit '*Technology and Underdevelopment'* in the light of subsequent research on – and criticism of - innovation systems. We argue a case for embedding the analysis of technological packages or systems in policy, and for the analysis of policy in the politics of markets. In the second part, we develop the first stage of such a political analysis of markets pertaining to the 'D' of technology in order i) to attempt to explain the retarded development of apparently appropriate solar energy technology in India and ii) to evaluate the weights of explanatory factors emphasised in 'Technology and Underdevelopment' (TandU) and those of later approaches.

PART ONE
Technology and underdevelopment

TandU starts from the inappropriateness of much technology in DCs (Stewart 1977, pp xi-xiii). Two questions arise: i) is the right technology not available to decision makers? or ii) are wrong choices being made by them? FS answers 'no' to the first and 'yes' and 'no' to the second. First, there is usually more than one technology available. Capital intensive, second hand, 'obsolete', traditional DC and new DC technologies may co-exist inside the set of 'world technology' (op. cit., p22-25). Even a range of efficient technologies may co-exist, particularly if the problem of choice is redefined from being one about a specific product to one about specific kinds of human needs (pp170-3, 196-204). So a prior problem to that of choice is, she argues, one of information.

Second, even informed choices may be wrong because the selection mechanism is the product of existing technological arrangements (p92) and cannot be used *ex ante* to change them. In TandU 'D' is the development of technological goods and services sold from ACs to DCs on terms favourable to ACs. 'Choice of technique' ought to be the choice not to be technologically and politically dependent (pp168-77). However, what happens in practice is that pressure from 'complementary processes' (p276) - one of which is the development of a local alliance of interests in AC technology – reproduces an AC environment for investment, factors and products, and results in a modern ('F') sector with high incomes but

[4] Henceforth FS

limited control over the relative prices set by AC technology. This sector then develops what is now called lock-in or path-dependence. Its technological dynamism serves to increase the gulf between the F sector and the needs of the mass of people (the 'L' sector) in poor countries over time in ways which become increasingly unavoidable (pp83-90). Were technology appropriate for labour surplus economies to be made available it would 'threaten the efficiency of th(at) existing system' (p278).

Her answer to the second question involves a paradox. The choice of the right technique requires the right technology and the right technology requires economic changes that are likely to occur after rather than before this technology emerges. As a result, although technology may be inappropriate for the factor endowment and inappropriate for domestic mass needs, it may be appropriate for elite demand if it substitutes for imports and it may also be appropriate for export markets.[5]

No sooner had TandU appeared than its argument was engulfed by structural adjustment, liberalisation and globalisation. How has it stood the test of time? Our discussion will focus on three aspects of TandU: institutions, energy, and politics and policy.

Institutions

One of TandU's insights is that 'technology is a package and each technique is designed to be operated within a particular *technological system*' (our italics). The elements of the system - 'associated processes' (p276), or 'linkages' (p81-3) - pervade the book. They include information / knowledge (pp2-3); the organisation of production - which affects capacity utilisation and management as well as upstream and downstream linkages between techniques (p4, pp61-6, p194); the distribution of incomes - which shapes markets for the products of technology and which determines the opportunity cost of labour, which in turn affects technological productivity (pp66-74). They include infrastructure for communications, banking and insurance (p81); local scientific and engineering capabilities; legal and administrative institutions; managerial capacities; and last but not least an appropriately skilled labour force (p8, p74) with social services and associated infrastructure (p7).

[5] When capital intensive techniques are introduced into labour intensive economies the alternatives are the creation of a dual economy (right decisions for the wrong sector – the F sector leaving the rest (L) to develop inefficiently without appropriate science and technology (p72-3)) or development white elephants and 'generalised rust' (wrong decisions).

We are a long way from Zvi Griliches' classic and parsimonious analytical framework for innovations in technology which privileges relative prices and costs.[6] But, while in the territory of institutions, TandU is also far from the contemporary literature examining the institutional barriers to DC access to AC/global cutting-edge, F-sector technologies because unlike TandU the latter mostly takes for granted (and thus neglects) their labour requirements and employment multipliers, and their poverty reducing potential. [7]

FS's insight into the packaged nature of technology not only focussed on the currently unfashionable concern for employment but also fully anticipated the analytical framework for 'innovations systems' now conventionally used both to evaluate and to promote (or policy-engineer) the institutional system required to nurture new technology.[8] In FS's concept of 'technological system' and in 'innovation systems' there are sets of overlapping ideas which are getting at something important – the institutional ecosystem *other* than relative prices and information which needs to be in place for the 'D' of R and D to happen.

'Innovation systems' (IS) came into being to address the paradox of the invisible hand identified by FS: the price of new technology does not drop unless supply rises faster than demand but demand will not rise while the price exceeds that of established alternatives. Its insight is that the institutional ecosystem affects both the social legitimacy of the process, and social returns to it, and thus adoption, diffusion and relative prices. IS posits an interrelated set of 'actors', 'networks' and 'institutions' which may encourage or constrain the process.[9] Prime movers are technological, political and financial; networks for information are particularly important; and institutions include hard and soft infrastructure, cultural norms and organisations. There are 'policy implications' involved in all three and the approach stresses the interactions needed for choices which maximise allocative efficiency.

As an evaluative tool, IS lacks a theory enabling the identification of key actors, networks and institutions at the material level at which the system actually operates, hence it is unable to specify the dynamics of those

[6] Griliches 1957.
[7] For instance Basheer, 2005; Correa 2000; Barton, 2007.
[8] Another not incompatible subfield created by sociologists involves the idea of a 'market ecosystem'– and consists of the institutions and technologies of the value chain, its tacit knowledge, networks and collective action (Saxenian, 1994).
[9] Jacobsson and Johnson, 2000; Schneider et al, 2008

interactions which generate allocatively efficient outcomes.[10] 'Actor' is a term developed to replace 'agent' in a critique of the dualism of agency and structure, but this dualism has not been transcended in IS because 'structure' is represented by 'institutions'.[11] In IS, labour is not regarded as an actor. (There is scant concern for the jobs which condition social legitimacy.) 'Networks' reduce varied and incommensurable power relations to quantifiable and comparable nodes and flows. The joint concept of 'actor-network' indicates the possibility of emergent individual and collective agency. However in practical applications of IS, the analytical categories of actor, network and institution all prove to be substitutable.

In response to criticism, IS has been extended to cater for the need to specify outcomes, the need for detail, and the need for quantifiable indicators so that innovations systems may be rigorously compared.[12] Indicators comprise market outcomes including entrepreneurial activity, market formation, resource mobilisation; and social outcomes including knowledge and its control. The IS approach has normative ambition, in that missing features may be 'engineered'. Yet the 'government', which is so central to FS's system, is notable by its absence.

While FS has pioneered a concept of policy as a technology,[13] she cautioned that the existing system forecloses options in technical choice. At best a technological system will be subject to 'institutional co-evolution' (among which FS placed greatest confidence in institutions of S-S trade).[14] The institutions identified as the technological system in TandU have withstood the challenge from IS.

Energy
'How does mankind live? …By sunshine…The starting point of economics should be the first and second laws of thermodynamics'[15]

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[10] Indeed the idea that it is intuitively obvious has been used by Callon (1991, p152) to argue that such networks can be understood as a 'black box' whose behaviour is known – 'heavy with norms' - and then drawn on as resources by other networks, in which case they are said to be 'punctualised' (Goodman, 1999, p27). Entire complex technologies or technological packages may thus be taken for granted until extreme events which test or destroy them thereby reveal their components.
[11] From actor network theory emerging from Crozier and Friedberg's 1977 critique of structuralism and pioneered by Latour, 1987, 1994, in his studies of the power relations of science.
[12] Hekkert et al. 2007
[13] For which she was honoured as one of the world's top 50 outstanding technological leaders in 2003 by Scientific American.
[14] Her attention to collective action and groups was to emerge later, cf.(eds) Heyer, Stewart and Thorp, 2002
[15] Juan Martinez-Alier quoting Soddy discussing Marx's neglect of energy (1990, p135).

Technology is not purely a social product. It also depends on materials and energy. The incapacity of the biophysical system of the planet to cope with the by-products of development is the most important social problem of the 21st century. So how energy was treated in TandU affects its contemporary relevance. FS handled energy in several ways: as a resource, an input, fuel (known as 'blood' to Kenyan maize-grinders) (p2,7,24,pp221-2, 246); as the basis for labelling techniques (e.g. hand /water/ diesel) (p229); as a capital goods sector producing an intermediate good (p152) both sector and good being subject to great technical vitality and dynamism and being characterised by lumpily substitutable techniques (p146); as a source of obsolescence (p12). She used energy as an example of inappropriate technology as opposed to 'sources of energy like sun and wind which are abundantly available in third world countries' (p60) but she did not pursue further this insight which is central to the second part of this essay.

In the 33 years since TandU was published, global warming has become the biggest threat to development and vice versa. We conceive its threat in several dimensions: physical, economic, political, ontological, even 'existential'.[16] To FS's final clarion call (p 278): 'what is needed above all is local technical innovation directed to local needs' has to be added: what is needed above all is technical innovation which minimises greenhouse gases and maximises the physical efficiency of materials and energy and the creation of jobs. The AC technology which has introduced the distortions of the F sector into DCs is now disastrously inappropriate for ACs as well.

FS argues consistently that alternative technology has to be 'introduced as a system if it is to be efficient' (p110). She recognised that a 'macro level change' (as would be implied by changed structures of subsidies to reduce fossil-fuel-based energy or by a generalised energy and materials minimising and employment maximising economy worldwide) would involve an *'alternative political economy'* with a 'different distribution of benefits' (p 277). Quite early on in TandU, FS concludes that the *'answer is to be found in the realm of politics rather than economics and technology'* (p112 (my italics)).

Politics and Policy

CO2e is being added to the atmosphere at the historically unprecedented rate of 2 % p.a. So the treatment of politics in TandU is also of central

[16] Dieter Helm, LSE 5.6.09

importance not only to FS's own argument but to the relevance of her argument to current circumstances.

FS defines a political economy as a distribution of control over resources (p73). While not wholly determined by techniques and technology, it is strongly associated with them (p110). At its heart, technical choice privileges 'different types of decision makers' (p73, 276). These include the government, which can have social as well as economic objectives (p22-4). Governments, however, are more often 'representatives of a particular political economy rather than its arbiters' (p272), which implies that the agency of the legislative and executive arms of the state is confined. The technological 'selection mechanism' (p92, 278) involves firms which vary in scale and in access to finance, together with policy-makers who also decide the sequencing and scope of physical infrastructure (pp22-4). Finally: there is political will (p278).

Comments on TandU

First, FS argues – and her fieldwork shows – that technical change does not occur by 'decision' but by many decisions in a process. Yet though the book is about decision and agency, and employment and poverty reduction, their corollary, social change, is conspicuous by its absence.

Second, FS's analysis is ambivalent about the relation between selection, choice and their opposite, dependency. 'Political will' is her way out of this corner. Not long after the appearance of TandU, Schaffer deconstructed political will as an escape hatch for planning elites to invoke when intentions and projects fail (1984). It is a political-academic 'wil-o-the-wisp' instructively replaced by 'political interest' by which we mean society's capacities to organise, make and implement decisions through the contested social relations which dynamise production (and reproduction). [17]

Third, state and government are conflated as representatives of a political economy rather than arbiters of social change. They are a constraint on decision making for L. In an important paper[18] Mushtaq Khan has addressed the view of the state as constraint, laying out what states must do and transformative states succeed in doing: create and protect property rights; develop agriculture, industry and services; and manage the costs of, and opposition to, these two projects. They must create incentives and

[17] This understanding of political economy is close to Bernstein, forthcoming ch 2 p6. Political economy was the original name for economics and its definition is evidently still subject to debate. Martinez-Alier, 1995, for instance, defines it as that branch of economics focussing on distributional conflicts.

[18] Khan, 2004.

gather revenue for promotion and protection of industrialisation; enforce rules and resource the inevitable political stability transfers; buy–off opposition from victims; and create and manage new political institutions. Not only is this a very tall order but its dynamic force is contestation. In TandU, L and F sectors are distinguished, but L does not actively oppose F,[19] labour does not oppose capital, different types of capital do not oppose each other,[20] nor are socially-regulated fractions of capital recognised as being at loggerheads.

Fourth, FS discusses capitalism using the terms 'economy', 'markets', 'firms' and 'labour'. Capitalist development is rarely mentioned and only in passing. In denying it a role and not examining its institutions, dynamism and politics, FS disables her own normative case for systemically appropriate technology.

Fifth, regulation is taken as given in TandU, yet it determines innovation adoption and is continually contested. If the fruits of applied research 'R' are novel, they will precede regulation, while the 'D' of technology must be regulated in the interests of the reproduction of any society.

Sixth, while it neglects regulation, TandU does not restrict policy to the decision on technology. It expands the concept of technology to include management, law and administration, thereby expanding the scientific scope of policy as well. But its treatment of policy as technology de-politicises policy. Many scholars have now shown how a de-politicised conception of policy is at the heart of aid-driven development busy creating fields of bureaucratic-cum-technical interest which, while they may fail in terms of their explicit objectives, succeed in their own perpetuation - and in so doing stifle other kinds of politics. [21] Policy for energy and climate change is no exception. [22]

The Politics of Technical Change

In the absence of the AC technologies known to exist and to be urgently needed, and to discover what is retarding 'D', alternative ways of

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[19] Nor does L provide necessary goods and services to F.

[20] Falkner, 2007, analyses in some detail the implications of dynamic conflicts over environmental policies and technologies between companies and sectors in the F economy.

[21] Ferguson (1991) Escobar (1995) – critiqued in turn for their overdeterminism and exaggerated focus on one particular development discourse, see Fernandez (2008).

[22] The 'mediation by science' of climate change is one of Giddens' four reasons for its uniqueness as a policy problem or 'issue'. The others are its abstract nature, its invisibility and its relevance to the future not the present. (Giddens, 2009). But its de-politicisation is a device for procrastination and the prevention of change. It has been balm to the elected, unelected and retired politicians responsible for reacting to the clamour for political will, many of whom also publicly ask for it, for instance Tony Blair, Lord Giddens and Lord Mandelson, LSE 5.6.09; Al Gore, Oxford , 7.7.09

thinking about politics of technical change are useful. Here David Dickson's contemporary histories of UK, US and DC science and technology politics published around the same time as TandU (1974, 1983/1988) are relevant.[23] Dickson's concern is closely aligned with FS's: the conditions under which environmentally safe technology which is appropriate for public needs might be developed.[24] Like FS, Dickson moves between the macro and micro, AC and DC, but unlike FS his analysis is grounded in the 'political conflicts and ambiguities underlying almost all technological decisions' (1988, p303). His meticulously detailed historical method reveals a politically-driven process in which, despite Friedmanite criticism of any public funding for science, state expenditure has protected basic science while, despite decentralised state control, states have targeted funding increasingly towards fields with military and industrial applications (computing, biotechnology, materials etc) (1988, p 2,39,44,pp72-7).

Dickson explains how the 'government' becomes no mere representative but an arbiter of the dynamic political economy of science and technology. Since this political process is the backcloth on which the current traffic of technological D moves, it needs a summary here. The process involves simultaneous feedback relations between 'science' (universities and public labs), the 'state' and 'industry'. Demands from labour and environmental movements for science and technology to be socially relevant prove 'a cacophony, making decision making difficult' (p53). They have been subdued by deliberate exclusion from decision processes and by increasing secrecy (p54).

The first set of feedback relations between science and the state become mediated by industry and party politics. University establishments which may be supposed to embody divided political loyalties (p106) have moved towards a position hostile to 'state interference' and easily capturable by private funders. Dickson strives but fails to refute the hypothesis that scientific evidence is subordinated to commercial interests. And policy based evidence parades as evidence based policy (pp22-25, ch 6).

The second set of feedback relations involves science and industry. Increasingly science and business become politically unified and opposed to control by the state (pp86-95). 'Corporate science' funds university

[23] So is the study of discursive framing and the various trajectories of scientism in policy processes but space prevents this. It was laid out in Schaffer (1984) and is well reviewed in Greenhalgh (2008, Preface and Ch 1).

[24] Dickson's solution is a democratic process of technology development which would work to a logic in which markets operate within parameters set politically in the public interest.

research, supplementing public funds and privately appropriating the D phase of public research, where ownership is key to political control and regulation. It is then a short step for industry to expand control from D to publicly-funded R (pp66-95).[25]

The last set of feedbacks relates industry to the state. Privately appropriated technology becomes an instrument of foreign policy. Skilled labour is invited in one direction, and technology is allowed to be exported if it reduces production costs and can be closely controlled - for exported technology has the potential to be used to compete with and erode the carefully constructed metropolitan 'competitive' advantage (1988, ch 4). In FS's terms, the 'government' and 'firms' are now politically fused.[26] Policy making then comes under the aegis of economics, which develops it as an exemplary field for cost-benefit analysis (p286). In FS's terms, 'decision making' and 'political will' become fused.

'The value of science as a policy instrument is both limited and dangerous' (p299) since there is no neat division between facts and values and the facts of science are open to more than a single interpretation. The paradox Dickson explains is that with the rule of experts and science instated in public policy, scientific autonomy and the state are undermined as the expression of the public interest. In terms of FS's framework, structure ('government') and agency ('decision-making' and 'firms') are fused.

It is not the inefficiencies of regulation that provoke this Polanyian swing of the pendulum towards 'market society'.[27] Rather it is the paucity of resources devoted to the public interest that disincentivises innovative investment and that capitalist industry therefore has to control (p302).[28] Moreover the unprecedented diffusion worldwide of a paradigm that Leys (2001) has called 'market driven politics' does not generate policy

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[25] For the first time in history, cutting-edge military technology develops independently of direct, formal state control (Willetts, 2002).

[26] In the US case, through mechanisms such as tax incentives, protective patent and regulatory reform (justified to create domestic 'international competitiveness') and controls over the export of knowledge, by the mid 1980s a class of corporate, finance and military interests were taking over the US research agenda (p49,89,185). Their political instruments include multilateral private funding of centres of excellence, open-ended private funding with the donor controlling patentable outputs, private donations matched by Congressionally approved funds, spin-offs and consultancies by publicly funded technologists to industry. R and D are re-conceptualised as investments (p33,53).

[27] On the contours of the contemporary Polanyian swing, see Stewart, 2009; Harriss-White 2009.

[28] See NFU, 2005, for a contemporary manifestation from British capital

coherence.[29] One of the reasons for policy incoherence is that conflicts within 'industry' weaken it relative to the state and civil society.[30] Elsewhere we have argued that this incoherence also emanates systematically from the transformation of some core functions of the bureaucracy – advisory, regulative and disciplinary - into fields of accumulation through the logic and the disciplines of commodification.[31] Commodities are not only invented with new technology, they are also transformed from non-commodity forms. The process has engulfed agriculture, the commons, the home, the building blocks of life, and the public sphere including the policy process. Capital's inability to halt the process of commodification is undermining its own regulative needs.[32] Domestic market politics is also part of the structure of the global deals at stake in 2009. Scaled-up, there is international market-driven politics; scaled-down there is national and local market-driven politics, with the precise balance of forces being context specific.

This necessarily compressed account remains the market-political context for the development of low-emission technology in ACs, and its transfer to DCs, as called for by the Stern Review of the Economics of Climate Change (2006). Renewable energy (RE), in which the energy transfers in production are too small to deplete the resource (Helm, 2004, p348), is an 'F' sector technology that is a 'prior' to the rest of the new technological and industrial revolution. While RE research is not a key constraint, the problem lies in its D in high-emitting ACs, its diffusion to developing countries and the politics of its D there. RE remains a 21st century example of the paradigm of the technological dependence criticised by FS in 1977 but its development is inappropriately slow almost everywhere.

So the second part of this essay initiates an analysis of renewable energy focussing on D, on solar technology, on the politics of markets, on the institutions FS identified in her expanded conception of a technological system, and on India.

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[29] Helm (2004) and Prins and Rayner (2007) use eclectic approaches to British energy policy analysis and conclude that it is incoherent.

[30] See Falkner, 2007; see Buck, 2007, footnote 25, p70, for the institutional variety involved in climate change response. In a political analysis of the UK energy sector to 2006, Harriss-White and Harriss (2007) showed that the politics of energy markets prevents the development of renewable energy through both party politics and non-party politics, the latter taking both democratically open and concealed forms.

[31] See also Leys, 2007, ch 3

[32] So much so that in energy, as of 2007, the British state was not able to define (and regulate in) the public interest, the long term interest, nor able to mediate between the conflicting interests it was discursively hell-bent on denying exist (Harriss-White and Harriss, 2007).

India makes a valuable contrast to the US/UK because a) while a democracy it is still a developing country, b) it has an energy policy statement that is politically coherent[33] and c) its energy economy is so much more state-controlled that to use an analytical frame privileging markets might be regarded as perverse. But, as Polanyi wrote, it is laissez faire that is planned while planning is not, [34] so this context for an exploration of the scope of a political analysis of markets in technology development is justified.

Market politics must therefore cover direct state economic control and participation, the indirect parametric regulation of private competition, as well as the politics of industrial organisation through which economic power is structured in markets, the collective action without which competition cannot take place and the key social institutions in which markets are embedded.[35]

PART TWO
'India'

'India' is a complex symbol in the international climate-change policy debates. Along with the US China Brazil and South Africa, India is key to the limited Copenhagen climate 'deal' made by non-signatories to the first round of the Kyoto treaty. In the analysis of the fall-out of the failure to create a second global round - which includes the reassertion of climate change denial - domestic politics have been neglected. While ACs see India as a threat in flow terms, 'India' (i.e. the state, the media and the policy commentariat) sees the problem in terms of CO2 stocks, with 'India' as a victim of the pollution of ACs. [36] India argues strongly for international technology transfer to DCs. It does this at a time when India's growth has produced inequality rather than eradicated poverty, its contemporary 'technological package' has produced jobless growth rather than mass employment and its consumption patterns produce CO2 at the top end of the income distribution at levels approaching those of N America (20.6 tonnes pppa), departing rapidly from the eventual 'CO2-stabilising' world average of 2 tonnes. [37]

In 2010, over half of India's 27,000 villages (and 487m people) are still off-grid and depend on state-distributed and subsidised kerosene, on

[33] Integrated Energy Policy, 2006. With its emphasis on coal it is environmentally reactionary.
[34] Polanyi, 1944
[35] White, 1993
[36] Panagariya, 2009, pp40-44
[37] See Billett's content analysis of Indian media, 2009. The UK/EU's average is 9 tonnes; India's currently is 1.2 tonnes (UNDP, 2007).

animal and human energy, candles, and biomass including cow-dung and charcoal. India's demand for primary energy is expected to leap from 400m toe[38] to 1200m toe by 2030, by which date the per caput consumption of electricity is expected to have tripled from its current 660kWh/cap (7% of the OECD average) to 2000kWh.[39] Currently 75% of this electricity is generated from coal and lignite, relatively and absolutely the dirtiest sources. They are justified as the resources of preference both because of huge reserves under state monopoly control and also because of the legitimacy and immediacy of the objective of poverty eradication.[40]

Yet solar energy technologies have the estimated physical potential to provide for up to 94% of India's additional electricity needs by 2031-2. India plans to add 640GW. The upper-end estimated potential of solar energy is estimated at 600GW, according to the Indian Renewable Energy Development Agency, not to mention wind, upgraded bio-mass and small hydro which exceed 100 GW (McKinsey, 2008). In addition, solar energy can leapfrog grid extension. Its employment multiplier is greater than other forms of renewable energy.[41] It can contribute significantly 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 the latter's externalities and current subsidies are factored-in*.[42] This potential was recognised in India during the brief period in the late 1970s when, reeling from the second oil price shock, many OECD governments together with China encouraged publicly funded science to explore alternative energy.[43] The elements of an Indian 'technological package' or innovation system were engineered in the 1970s and 80s on a time-par with Germany and well prior to the impetus Rajiv Gandhi gave to the unfolding process of liberalisation. But these elements were not sufficient to give a significant boost to alternative energy.

Solar energy at present supplies only 0.75% of India's electricity.[44] Just 5% of the Ministry of New and Renewable Energy (MNRE) budget is devoted to solar under the 11th Five Year Plan.[45] Meanwhile fossil-fuel

[38] toe = tonnes of oil equivalent
[39] Installed generation is planned to expand from 160 to 800GW by 2031-2. See *the National Action Plan on Climate Change*, GoI 2008a
[40] GoI's *Integrated Energy Policy*, 2006
[41] 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).
[42] WISE, 2008. Large hydro is also heavily subsidised. Externalities have never been costed.
[43] Dickson, 1988; Martinez-Alier and Schlupmann, 1990, p18; Schneider et al 2008
[44] 1.2GW out of a total generating capacity of 160GW in 2008 (McKinsey, 2008)
[45] Government of India, 2008c

based electricity generation continues to benefit from a very large set of public support measures and subsidies – averaging 150% of the capital costs of projects between 1993-2003.[46] It is in both the national and the global public interest that India develop solar and other renewable energy. There are powerful sectional interests on the other side however.

In mid 2008 the Indian Prime Minister pledged '*all our scientific, technical and managerial talents with financial sources to develop solar energy.,* [47] Just 6 months later India's Integrated Energy Policy was formally accepted by the Indian government with RE in its entirety planned to account for no more than 5-6% of the energy mix by 2031-2. In August, 2009, the Indian government changed this target to 25% for solar alone, but only provided it is aid-funded.[48] Moreover, while the National Solar Mission was launched in 2007, a new 'Jawaharlal Nehru National Solar Mission' was launched in November 2009.[49] Why this instability? Why have 'sources of energy like sun and wind which are abundantly available in third world countries' (TandU p60) 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?

To answer FS's questions, the institutional architecture for solar energy was researched in an application of the extended framework for the politics of the technology system and its markets that has been developed here (Harriss-White, Rohra and Singh, 2009). It is summarised in the Appendix. In what follows we outline the implications of this architecture for the political and social relationships at stake in the 'D' of solar energy.

State control: The 1970s technology system for RE privileges institutions, which (as for the energy sector as a whole) are under public ownership and control in order to encourage research, to disseminate technology and to protect infant industries at all scales, ranging from the assembly and export of grid-connectable applications (the main present orientation) to

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[46] WISE, op cit pp 73-80. Fossil fuel energy is also taxed; but it is the structure of subsidies not the taxes which determines the competitive advantage of the energy sources.

[47] *'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*' (Dr Manmohan Singh, launching India's National Action Plan on Climate Change, June 2008).

[48] Rahman, 2009. The demand for $20bn of dedicated bilateral aid contradicts India's Copenhagen position for a multilateral technology fund – being opposed by the G8. See pp17-18 here.

[49] This has an upwardly revised solar target of 20,000 MW by the end of the 13th Five Year Plan in 2022, a 17-fold expansion on 2008, together with a single window investment facility.

the supply of rural off-grid appliances. The solar technology system is part of the remit of the State Electricity Boards, it is scattered throughout several Ministries and many state bodies, and marked by their proliferation, an acceleration of central government policy initiatives, a surge in discursive support, under-funding (particularly for capital subsidies), and discretionary policy at state level (e.g. long term solar energy purchase contracts). This structure of intervention has led to widely differing state trajectories. RE as a whole is marginalised. Furthermore, within RE, public sector wind has been favoured over solar, even though India has problems with intermittency.

State regulation: Only recently have the drivers of solar development shifted towards private capital. Markets not only require a legal-regulative framework and finance; they require infrastructure, sites, information, supply chains and entrepreneurs. Private and state firms are regulated through the Electricity Act of 2003 which vests the central state with authority to specify policy, tariffs, grid transmission standards and dispute resolution but without mandatory powers of enforcement. Regulative discretion for the private sector includes tax exemptions and guaranteed rates of return for exporting firms. International IP rights are reported *not* to have prevented the development of private solar technology. This happens through licensing and joint ventures.

India's regulative institutions operate a two-track approach – manifest both in state participation and direct control, and in private sector regulation, and visible in other areas of policy such as food. It results in domestic technology policy and institutions which are operationally incoherent at different political scales. While the domestic duplication/copying/reverse engineering of innovations made elsewhere is advocated, so too is the (free) international transfer of technologies, to be funded by ACs.[50] While India's international politics supports the transfer of ownership of IPRs, national politics supports licensing and imports. While R is designed to be in state hands it is now being de facto privatised.[51] 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 marginalised by conventional energy corporations. Hybrid institutions of state control and private regulation and a diverse policy ecology generate high co-ordination costs between state and market interaction as when feed-in tariffs have to be negotiated at state level only if triggered by private suppliers who have to make investments in advance.

[50] Singh, 2009, p11; Rahman, 2009.
[51] The ease of import exacerbates disincentives for the domestic R being encouraged in the IIScs.

Industrial organisation: The markets for manufacturing and retailing off-grid appliances are polarised between niche interests of industrial oligopolists on the one hand, and a mass of small specialists, many in the informal economy, on the other. Markets are so constrained that some major companies depend on local NGOs in unstable hybrid delivery systems to reach the bottom of the pyramid. By contrast, grid-compatible technology is a sector with three state corporations, 9 private solar cell manufacturers, 18 photovoltaic (PV) companies, a 'handful' initiating thin-film applications, plus small firms manufacturing components and bespoke applications.[52] Intermediate goods and raw materials (ingots, wafers, thin film silica, et al.) are imported, many from Japan, and 70% of what is manufactured is exported, mostly to Europe. Informal contacts enable Indian entrepreneurs to find ways of acquiring the most protected element – process technology – in the face of the indifference of their own finance capital.

Organisation of finance: The Centre and the states struggle to maintain their selective and significant subsidies and support measures on coal, gas, oil, hydro and nuclear. States reel under subsidy burdens for agricultural electricity, itself the result of party political competition. The state electricity boards themselves are saturated with locked-in subsidies. As a result - and reinforced by the pressures of neoliberal politics - the resources required to subsidise RE are not forthcoming. The private banking sector is risk averse and has a feeble record for RE compared with state funding agencies. The immediate lumpy capital costs dominating loan use for RE are severe disincentives. Only one solar plant has been funded through private equity and the capital markets. Yet despite state finance agencies being supplied with funds from the private sector which are then lent onwards at higher interest, the supply of solar finance is overwhelmed by demand. International development banks, UN agencies and NGO-development agency hybrids have started to finance solar applications.

Private collective action: There is no constituency for RE in the Indian trade union movement.[53] Even the political activity generated by industrial associations falls far short of the invasion of the policy process by business interests as in the OECD heartland. There are – only three solar business associations (listed in the Appendix). They are engaged in improving public knowledge and reducing the social distance between research and business. The four major general industrial lobbies (listed in the Appendix) have acknowledged RE only very recently, are developing

[52] In 2009.

[53] There is also remarkably little technology literature which considers employment, not only in India.

a field of information rather than one of investment or of policy, and do not speak with one voice. Collective action is an element of political contingency.

Social embedding: An informed policy elite is essential to supply the political leverage needed to release the limiting constraints on D. But solar energy is part of a political culture that has given low priority and status to RE and its ministries and agencies. It is part of a social culture that has prevented easy contact between publicly funded science, entrepreneurs and society. India has had RE research institutions in place for two decades with little impact on solar energy or society. Only 12 university departments are research-active in RE and the skills vacuum is so intense that some Indian firms plan joint research ventures abroad. With the exception of the World Institute for Sustainable Energy (WISE) in Pune, and The Energy Research Institute (TERI) in New Delhi, the think tanks, some with industrial funding, have also placed solar on their margins. Environmental movements are fully occupied with the agenda of forest problems, GM seeds, urban air pollution, toxic waste and industrial accidents and RE has no constituency. The media has focussed on greenhouse gas stocks rather than flows, on environmental justice and - if at all - on solar as a means of adaptation rather than mitigation. Despite endorsement from the PM, civil society is generally ignorant about solar energy and its possibilities and it is left to a very small number of institutions with different interests to strive to establish its legitimacy.

Conclusions

In this essay we have tested an approach to the understanding of technology and development which is complementary to TandU's while building on some of FS's conceptual tools. It situates technical change in the politics of markets, embedded in state policies and social institutions. 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: FS conceived technology as having many elements – a package – and included many institutions among the factors making a technological system in which the package develops. They are listed on page 4 above. While the parsimony of the institutional toolkit of the conventional 'innovations systems' approach may appeal, the case of solar in India confirms the importance of the expanded list, in particular FS's inclusion of infrastructure for communications, banking and insurance; scientific and engineering capabilities; legal and administrative institutions (here: IPRs and

licences); managerial capacities; and an appropriately skilled labour force. ‘Banking’ needs expansion to include institutions for finance, aid, subsidies and support measures.

These are *general* requirements often missing from the analysis of the existing or theoretically desirable ‘innovation systems’ for a specific product.

The case of solar also reinforces the theoretical argument for a political approach to technical change and our evaluation of long-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 market and conceiving the choice of technique as an element in the development of capitalist markets. Capital must expand and in so doing it strategises to introduce new technology, reduce labour costs, transform state-protected sectors into fields of profit, and persuade the state to support a process which threatens the state itself. The state must then fight back and also select those risks it will bear, or capitulate.

Key institutions are those of state control/‘participation’; state regulation facilitating change; the (self- and state-regulated-) organisation of market structures which affect 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.[54] To understand these institutions and the politics of the interests they reflect needs 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 has been one of the main purposes of this essay.

Substantive Conclusions: The research reported in this chapter has revealed a different balance of political forces from those described by Dickson and summarised earlier. Starting with the hypothesis that technological change is conflictual, Dickson built an analysis of politically fused/hegemonised institutions and agency. FS with a similar institutional toolkit modelled the state as representing a particular political economy. But in India’s solar sector, science is not fused with capital – there is hardly any relationship between the two. Science is subordinate to the state and while there certainly is rule by experts in the

[54] In India’s dominant informal economy these form a social structure which tends to stabilise accumulation (see Harriss-White, 2003)

Planning Commission, RE policy is not made by RE experts. Nor is there any sign of the general mobilisation of science demanded by the Prime Minister. . The state's RE technology system, with just 12 under-funded research departments active in RE research, is inappropriate for capital. Yet the state is ceding agency to it. There is as yet a very tenuous feedback relation between capital and the state. Finally, civil society is weak not because it has been disabled as in Dickson's scenario but because it has not yet been mobilised.

The Indian state embodies the interests of a range of technology systems. In RE, the state created the institutions to develop RE but did not endow them with power to challenge state-owned incumbent technology. Although no established energy institutions have been threatened, and RE was at the time not envisaged as the essential precondition to a materials revolution, RE has been treated as though it were a threat. What our analysis shows is how the politics of the technological system for RE has *by itself* been sufficient to disable 'D'.

In TandU, FS asked whether the right technology is not available or whether the wrong choices are being made. The answers here are 'no but' and 'yes but'. RE - even solar – is not one technology but a set of them, each one with components making a 'package'. The right technologies are available and are not obstructed by patent law so much as by the structure of domestic subsidies, the reluctance of banks, price instabilities and the co-ordination failures of the technological package built to facilitate them. The wrong choices are locked-in to India's energy system through the non-transparent, life-cycle and life-time requirements of fossil-fuel technologies dominating public support and infrastructure. The wrong choices are also the product of public finances locked into subsidy burdens in other sectors. India is not unusual in this respect. It is unusual in its public support for renewable energy.

Initiated precociously early the subsequent development of the solar technological package has marginalised and dis-incentivised solar. The paradox of precocity and failure needs to be explained by the politics of markets in an energy sector still dominated by state ownership, and much more comprehensively state-regulated for development in the public interest than is food.

State institutions and politics: States can work without markets but markets can't 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. While the state is now creating by

increments a technological package for private capital, it is slow to redefine the public good as the good of private solar business. Despite the Prime Minister's discursive encouragement, and despite continual expansion of solar goals alongside rapidly receding dates for them, public institutions are not fast-tracking solar. Regulation is suffused with discretion and hard to enforce. Indeed, some regulative policy is *designed* to be incoherent, e.g. states competing to negotiate feed-in tariffs which are triggered only when business initiates them. This institutional architecture, in which evolutionary reform gives rise to complexity without destroying redundant institutions along the way not only generates inconsistency but also serves to stall the D of technical change. The state is incapacitated from operating in the public interest which would prioritise the rapid development of solar.

There is also a social and cultural distance between state, science and market institutions combined with low status for RE which cannot be altered by policy technology and institutional design by themselves.

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 Japan and Germany.[55] This 'F' sector technology is not prevented from flowing to a technologically capable country like India – indeed the Obama administration is now selectively encouraging business partnerships - but it flows at a price. 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. In the face of incoherent domestic policies for solar, and with the sector dominated by state enterprises plus a private oligopoly together with a large number of small specialist firms, India is developing technology for export which it needs domestically.[56]

Despite a well developed banking sector and a huge corps of innovative engineers, markets for money and labour do not support the sector. Apex industrial lobbies are at the stage of informing rather than representing the interests of manufacturers. Labour is inactive politically and given lowest policy priority as a factor of production. Trade associations and

[55] In the OECD as a whole including the US, R and D for RE grew between 1978-83 but atrophied thereafter. In the UK it declined in real terms between 1994 and 2003. Over the OECD, public funding for civil nuclear energy is currently 20 times greater [JH: greater than what?] (Jakobsson and Johnson, 2000; Schneider et al, 2008)

[56] 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 i) the post-TRIPs regulative context, and ii) limited patent constraints.

hybrid institutions of collective action struggle to establish the legitimacy of solar energy. The sector is poorly recognised by - and not backed by - civil society. Neither science nor the media have developed public education with respect to solar. Environmental movements have many other objectives than the promotion of solar and RE is a niche specialism in environmental thank tanks.

Calls for 'political will' face these complex manifestations of political interests. The global response to climate change requires a radical and rapid shift in technology, what FS called 'macro level change'. But RE, the forerunner of this change, cannot generate macro level change through the technological system constructed by the 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, is hostile to the 'new technological paradigms' to the development of which the Indian government itself is discursively committed. We have confirmed that what FS terms an 'alternative political economy' cannot be engineered through incremental change to a technological system that has developed internal structural and social inconsistencies through incremental change.[57] There are no precedents in a neo-liberal era for the institutional destruction needed to fast-track the technological elements of the new energy' revolution which must precede the revolution in materials.

Policy-relevant findings

First, this research suggests that India's *international political initiatives* may be mis-prioritised with respect to technology transfer. IPRs are no barrier to the expansion of advanced capabilities in solar. In the contradictory regulative framework in which India calls for an international funding body to remove a barrier that does not exist, India may be acting as trustee for the interests of less technologically proficient DCs.[58] And/or it may be looking far beyond imitative adaptation 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. The international attention on IPRs is distracting attention from more serious policy problems.

Second, equity in public support would either mean addressing the costs of the negative externalities of fossil fuel and nuclear energy and removing their subsidies and support and/or providing new forms of

[57] 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 CGIAR.
[58] The phrase is Barton's, 2007, see Singh 2009

energy, in particular solar, with comparable or greater public support measures as befits such socially valuable infant industries. In the neo-liberal order, RE is being required to develop without the kind and level of protection hitherto given worldwide to socially useful energy technologies. Not to support RE is an extraordinary historical anomaly, not simply in India's response but in the global response to climate change. Prime among the problems here 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 of the cost to society (and the pressures on public finance) of conventional fossil fuel-based, hydro- and nuclear power*. No complete calculations of energy subsidies and support measures net of tax have ever been made. This is the problem needing international funding. This is a *general* policy implication for 'D' - drawn from literature not confined to India. [59]

Third, while this essay has revealed the combinations of the institutional complexity and low status of solar energy's technological system as formidable obstacles to its development, *the limiting constraint on solar energy 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 solar finance has been the preserve of public banks for public sector initiatives or 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.

Finally the institutional life of solar energy has been not so much a process of technical choice, but rather a painfully drawn-out *process of resistance* both to indifference and to developments opposed to solar 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 -'official transcripts' - in which plans for solar are pushed to the margins. Official transcripts of the government of India on Copenhagen include: Integrated Energy Policy 2006; and National Action Plan on Climate Change 2008b. *Resistance* has been theorised as a

[59] WISE, 2008, scoured the literature worldwide finding limited evidence, which nevertheless indicated extensive subsidies on energy from fossil fuel.

property of subaltern classes, expressed both openly and through 'hidden transcripts' – the private 'offstage' dialogue about practices and purposes.[60] The latter awaits research. That the 'D' of solar so far has been an act of elite resistance is not so far-fetched a conclusion when faced with mass denial about coal and lignite as not being the natural order, as not being the arrangement making 'pro-poor development' possible, and 'cleaner coal' as not being the paramount technological imperative. These are all carefully constructed 'foregone conclusions' and 'policy imperatives'.[61]

Multiple institutional failures in India's technological / innovation system for RE have yet to be tested as reflecting the success of the politics of resistance by the established energy sectors in public ownership.[62] However using the expanded framework developed here we have shown how the political architecture and interests are changing and it would be a mark of greatly needed progress if, unlike TandU, our substantive analysis were *not* to stand the test of time.

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[60] Scott, 1990
[61] Schaffer, 1984
[62] 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 Chatterjee, 2009, on coal politics.

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APPENDIX 1. INDIA'S TECHNOLOGY SYSTEM AND MARKET ARCHITECTURE FOR SOLAR ENERGY

		1970s	1980s	1990s	21cent	proposed
State participation/control	central	1976 Dept of Nonconventional energy IITs/IIScs (public res)|	1980 National solar PV energy programme 1982 Solar Energy Centres 1987 Indian RE Devt Agency	1992 Min of New and Renewable Energy	2002 off-grid appliance subsidies 2004 Renewable Power Obligations (non-mandatory) 2006 Technology Incubators 2007 Export Incentive Package 2007 National Solar Mission2008 On-grid (feed-in) Policy 2009 J Nehru Solar Mission	
	states	State Electricity Boards State Power and Grid Corporations	NSpvEP Nodal agencies	1994 Network: Aditya outlets – offgrid appliances	SEZs Feed-in tariffs (selective) 2007 SIPS [?here?]	Joint ventures for research InternationalIP transfer to pvt sector Solar parks, and solar in technology parks and industrial townships
State regulation of private markets		1970 Patent Act - products		1999 Patent Act for process/TRIPS compliance 1999 Central (Elecy) Act (tariffs / terms + conditions of trading and transmission/standards/ dispute resolution	2002+ RE under SEZs / tech parks 2008 IPRs in univs 2009 National Incentive Package scheme	
Industrial organisation [Lines/boxes in this section-> need to be changed – can't seem to do it myself … JH]	Off grid On-grid			Many appliances pub and pvt oligopoly/ some vt-NGO hybrids for [?]BoPmkts[?] mass of small specialist mfrs and retail	-> Thermal and PV – ingots/wafers imported from Jap/USA/Ger 3 public corporations, 9 pvt solar cell mfrs, 18 PV firms 12 firms licensed to mfr for export Thin film amorphous silica imported by 'handful' of firms	
Finance			1987 Indian RE Devt Agency		Global-regional and national public finance to state agencies / IFC few pvt equity ventures Foreign aid Retail: NGOs, NGO pvt hyrids foreign aid	

Private collective action		1976 Solar Energy Society of India for Public R+D and education FICCI ASSOCHAM	1988 NASSCOM	-> 1992 CII (devd from Eng Assocn)	Institutional hybrids Solar Equipment Materials International – res and pvt sector links Indian Semi-conductor Assoc – public knowledge 2009 US-India Solar Energy Partnership 2009 FICCI conf / Min of Envt 2009 ASSOCHAM:RE conf Energy effic x RE 2008 CII starts work on RE No trade union activity on RE 2009 NTUI + >100 envtl orgsn create cl change memorandum	Energy efficiency xRE
Social embeddedness	science	RE low status Little specialist education	->	->	-> ->	
	envt movt	-	->	->	RE marginalised	
	think tanks				TERI RE=4/218 publns in 2007-8 – feasibility studies for pvt sector SCE - WISE Centre for Solar Energy	
	media				Focus on Wind /stocks / justice xRE	

Sources: see Harriss-White,Rohra and Singh, 2009; Mallet and Haum, 2009