Clean development mechanism – an opportunity to mitigate carbon footprint from the energy sector of India

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Clean development mechanism (CDM) was included in the Kyoto protocol to support sustainable development in developing countries through technology transfer from developed countries along with the mitigation of greenhouse gas emissions. More than 1000 projects which were registered under CDM from India in the United Nations Framework Convention on Climate Change have been reviewed. Through a CDM project, India as a developing country has enhanced the development of renewable energy projects with financial support through the sale of carbon credit. This note discusses the status and progress of CDM in India; the main finding is that CDM has significantly reduced the carbon footprint of the Indian energy sector.

The increase in atmospheric greenhouse gases (GHGs) is the primary cause for the anthropogenic climate change. Although developed countries are accountable for majority of GHG emissions, the contribution of developing countries has also been significant[1–4]. The United Nations Framework Convention on Climate Change (UNFCCC) defines climate change as 'A change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods'[5,6]. Its main aim is to stabilize atmospheric concentrations of GHGs, while assuring food, security, adaptation of ecosystems and sustainable development[7].

As a result, the Kyoto protocol has been adopted as an international agreement under the UNFCCC since 1997 and entered into force in 2005 to reduce GHG emissions. Joint implementation, emission trading and clean development mechanism (CDM) are the three mechanisms involved in the Kyoto protocol. CDM has gained priority in developing countries because of the economic benefits from this mechanism[5]. One of the main commitments of industrialized countries (Annexure I countries) in the Kyoto protocol is to reduce their GHG emissions to an average of 5% below their 1990 levels over the first commitment period[8–10].

Under CDM, Non-Annexure 1 developing countries will be benefited economically through certified emission reductions (CERs) for sustainable development in the host country, these CERs would be traded with Annexure 1 developed countries to meet their part of emission reduction commitment assigned to the Kyoto protocol. The primary objective of the Kyoto protocol is to support sustainable development in developing countries. Sustainable development is measured by the following indicators: social, economic, environmental and technological well-being of a country. These involve generation of employment,

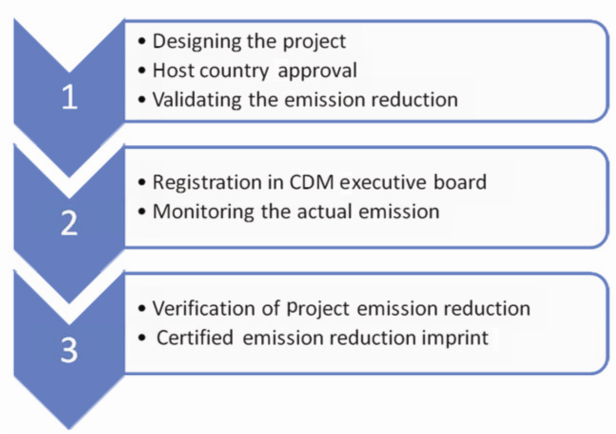

Figure 1. Clean development mechanism process (source ref. 13).

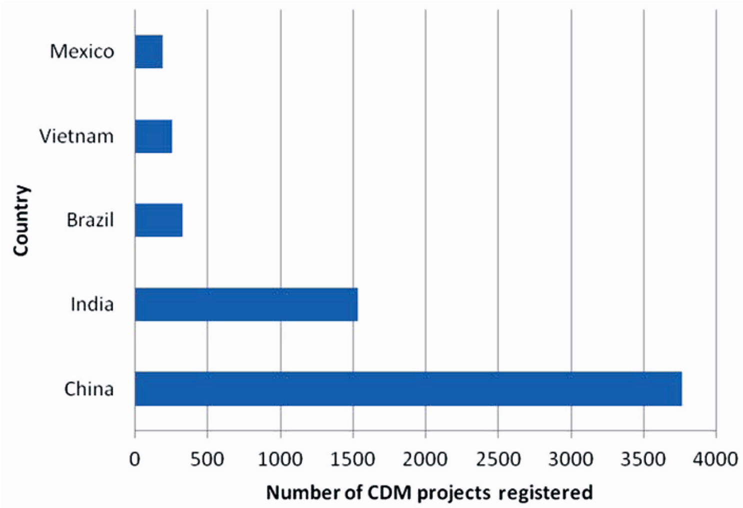

Figure 2. Top five countries with highest CDM registration (source: data analysed from ref. 13).

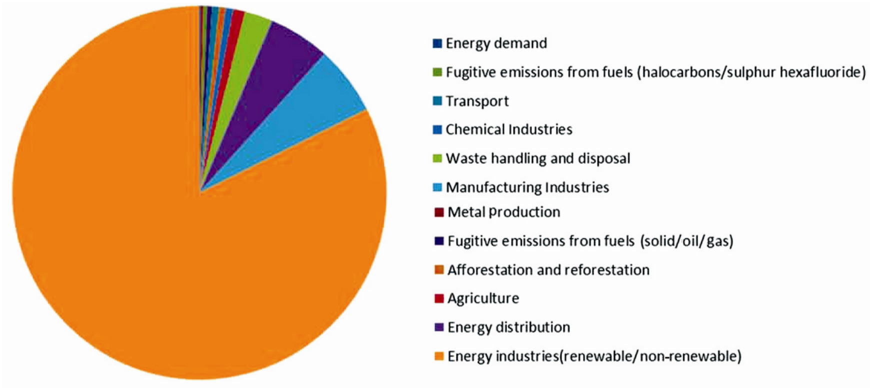

Figure 3. Distribution of categories in Indian CDM projects (source: data analysed from ref. 15).

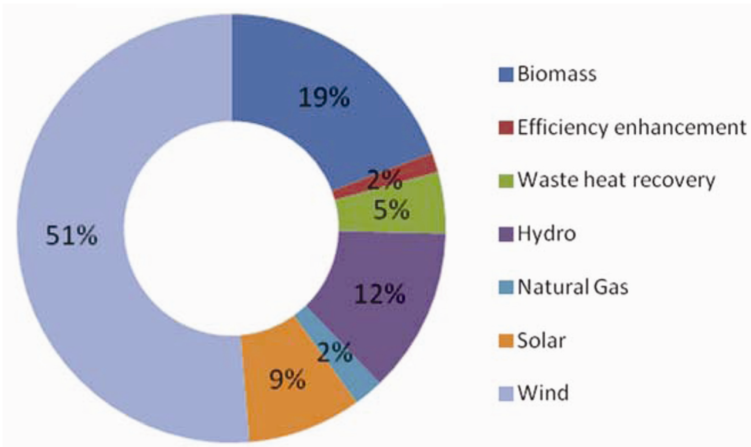

Figure 4. Distribution of number of projects registered under CDM from India (source: data analysed from ref. 15).

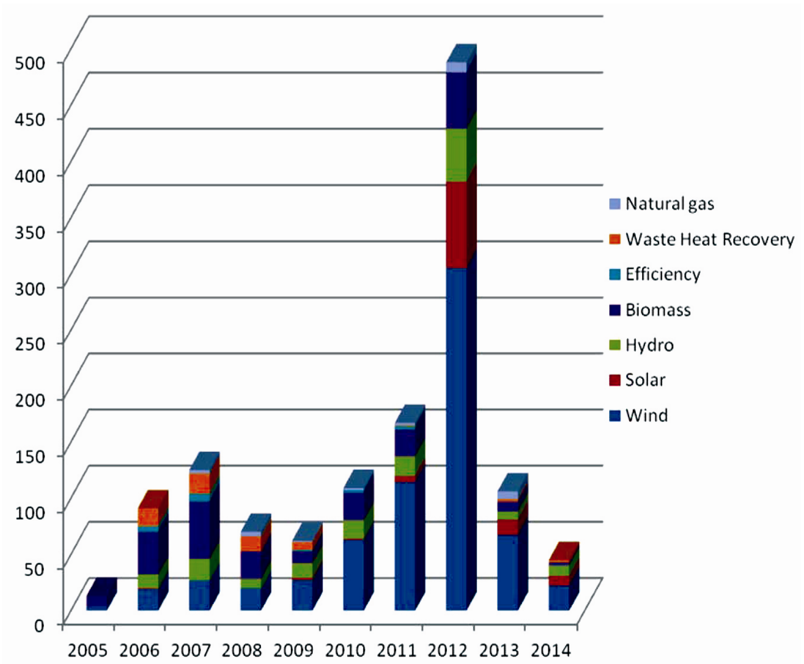

Figure 5. Year-wise number of CDM projects registered in India (source: data analysed from ref. 15).

additional investment towards development, mitigation of pollution and to shift from older technologies to advanced and cleaner technologies[11,12].

The Indian Government has ratified the Kyoto protocol in August 2002 to mitigate the GHG emissions[12]. Many projects in India have been successfully registered under CDM. This note is organized as follows: introduction to the project cycle, renewable energy opportunities in India, various methodologies in CDM and case studies to provide an overview of India's energy projects which are registered under CDM.

The process of registering a CDM project has a series of steps. It starts with a project design document (PDD). The project participant should clearly mention details of the emission reduction, technology, methodology applicable and all other resources related to the proposed project in a described format. The designated national authority (DNA) would issue a written approval after reviewing the PDD from the project participant, only if the proposed project is helpful in sustainable development of the country. On issuance of the national approval letter, the project participant approaches the designated operative entity (DOE) for validation. The DOE would validate the information given in the PDD by a site visit and clarify whether the particular project follows the Kyoto protocol. After successful validation, the DOE forwards the validation report to the executive board of CDM for registration. Once the registration has been initiated by the project participant, a monitoring report has to be prepared based on the actual site emission reductions accounted for and should be accorded with PDD, which should be forwarded to DOE. With proper inspection verification and certification report may be forwarded to the executive board. As a final stage of the CDM project cycle, the executive board issues the certified emission reductions to the project participant[13]. There are a series of rigorous steps involved in obtaining CER (Figure 1).

As on 8 November 2014, total project registers with CDM, in the UNFCC was 7573, with issuing CER of 1,506,931,713 to project activities. With 1532 registrations, India holds the overall second position in the world after China (3761). Figure 2 shows the top five host countries which are actively participating in

Table 1. CDM projects and their distribution under renewable energy industries (source: data analysed from ref. 15)

State/ Union Territory	Total	AMS 1D	ACM 0002	AMS I F	AMS 1 D	ACM 0002	AMS I C	AMSI A	AMS II J	AMS 1 D	ACM 0002	AMS I F	AMS I A	AMS 1 D	AMS 1 C	ACM0 006	AMS I A	AM 0004	AM 00018	AM 0036	AMS III B	AM 0015
Andaman & Nicobar	1				1																	
Andhra Pradesh	45	4	5		2					5	1			22	3	2				1		
Assam	1									1												
Bihar	3													1	1		1					
Chhattisgarh	22				2					1				17	2							
Goa	0																					
Gujarat	161	59	42	1	33	11				2				6	7							
Haryana	10				1					1				3	5							
Himachal Pradesh	57									39	16				2							
Jammu & Kashmir	2										2											
Jharkhand	1														1							
Karnataka	128	39	26		4		4	1		21	14			11	1	6						1
Kerala	10	2								7				1								
Madhya Pradesh	28	9	7		1					1				6	4							
Maharashtra	142	63	34		4				1	8	1			17	11	2					1	
Multi State	88	71	9		3		2	1							2							
Odisha	8				3					1	2				1				1			
Puducherry	0																					
Punjab	33									5				13	14			1				
Rajasthan	139	75	19		29	4								11	1							
Sikkim	6										6											
Tamil Nadu	219	164	33	2	1					2				10	2	3		1				1
Tripura	0																					
Uttar Pradesh	42				2					1	1			7	10	21						
Uttarakhand	16									7	4		1		4							
West Bengal	9									1		1		2	5							

Table 2. CDM projects and their distribution under non-renewable energy industries (source: data analysed from ref. 15)

State/ Union Territory	Total	Energy efficient					Waste heat recovery			Natural gas						
		ACM 0013	ACM 0006	AMS II B	AMS II D	AMS III B	ACM 0012	ACM 0004	AM 0024	AM 0029	AM 0014	AM 0009	AMS III B	AM 0084	AMS III AM	AMS III AH
Andaman & Nicobar	0															
Andhra Pradesh	15	1			1		1	3	2	7						
Assam	1							1								
Bihar	0															
Chhattisgarh	20						1	19								
Goa	1							1								
Gujarat	17	1		1		1		2		10	1					1
Haryana	1													1		
Himachal Pradesh	0															
Jammu & Kashmir	0															
Jharkhand	5	1						4								
Karnataka	5		1				1	3								
Kerala	0															
Madhya Pradesh	2	1													1	
Maharashtra	5	1					1	1					1			1
Multi State	0															
Odisha	9						1	8								
Puducherry	1			1												
Punjab	1		1													
Rajasthan	3							2					1			
Sikkim	0															
Tamil Nadu	7		1				2	2		2						
Tripura	1									1						
Uttar Pradesh	2				1							1				
Uttarakhand	0															
West Bengal	9			4	1			4								

Table 3. State-wise estimated greenhouse gas (GHG) emission reduction

State/ Union Territory	Estimated GHG emission reduction per year (tCO_2e)
Andaman and Nicobar	6,411
Andhra Pradesh	12,098,416
Assam	63,318
Bihar	101,793
Chhattisgarh	2,222,638
Goa	112,357
Gujarat	19,087,781
Haryana	284,089
Himachal Pradesh	10,611,161
Jammu & Kashmir	354,724
Jharkhand	2,400,770
Karnataka	7,219,578
Kerala	148,863
Madhya Pradesh	3,260,341
Maharashtra	5,706,433
Multi State	1,644,267
Odisha	978,528
Puducherry	8,791
Punjab	1,270,290
Rajasthan	3,144,183
Sikkim	4,113,688
Tamil Nadu	7,350,930
Tripura	1,612,506
Uttar Pradesh	2,881,324
Uttarakhand	2,050,911
West Bengal	600,204

Source: Data analysed from ref. 15.

sustainable development[13]. These 1532 projects were registered under different categories of CDM, namely energy industries (renewable/non-renewable), manufacturing industries, energy distribution, waste handling and disposal, agriculture, chemical industries, afforestation and reforestation, transport, fugitive emissions from fuels (solid/oil/gas), fugitive emissions from fuels (halocarbons/sulphur hexafluoride), metal production and energy demand. About 82% of the projects have been categorized under energy industries (Figure 3).

Several kinds of renewable energy projects have been registered under CDM. Wind energy dominates other forms of renewable energy production (Figure 4). Out of 1276 projects studied under the category of energy industries, 655 have been registered as wind energy, 246 as biomass energy, 159 as hydro power, 110 as solar energy and the remaining projects were registered under other sectors like nuclear gas, energy enhancement and waste heat recovery.

The most promising renewable source of energy is wind. At the end of 2013, India stands as the fifth largest wind energy producer in the world. All the wind resources in India are on-shore projects only with 19.1 GW installed capacity. The Ministry of New and Renewable Energy (MNRE) has taken steps through national offshore wind policy in 2013, to increase the offshore installation. It has identified potential offshore wind energy from Tamil Nadu, Gujarat and Maharashtra. The main objective of the policy includes developing manpower, encouraging research and development, and achieving energy security. Introduction of generation-based intensive scheme at the end of 2013 with an incentive of 0.5 INR per kWh for a period of 4–10 years has increased the investment in wind energy.

In India, solar energy has contributed only 0.8% of the total energy production. Estimated potential of solar energy in the country[14] is about 6 billion GWh. The Government has introduced the Jawaharlal Nehru National Solar Mission to reach the national target of 20 GW installations at the end of 2020 to increase the utilization of this natural resource. Till March 2013, 1686 MW has been installed, in which majority of the projects have commenced in Gujarat and Rajasthan.

In the case of biomass energy from forest and agricultural-based biomass residues, the MNRE has projected 18 GW of power potential in the country. Maharashtra, Uttar Pradesh, Karnataka and Tamil Nadu have the largest installations compared to other states in India. At the end of March 2013, the total installed capacity has reached 3601 MW. About 65% of biomass energy production in the country is contributed by bagasse-based co-generation from sugar mills. Apart from traditional renewable energy, MNRE has initiated research in hydrogen, fuel cells, tidal energy, biofuels and geothermal energy[14–16].

Most of the projects registered under the energy industry have been reviewed here. In Tables 1 and 2, projects which were registered in different states of India under the category of energy industries (renewable/non-renewable) are studied along with the methodology considered. Wind, solar, biomass have been separated from waste heat recovery, energy efficiency and natural gas projects for better insight regarding CDM projects in India. Along with Gujarat, Andhra Pradesh and Himachal Pradesh have been playing a vital role in emission reduction through CDM as shown in Table 3, which demonstrates the total number of cumulative estimated carbon credits owned by the states in various projects. Tamil Nadu has the highest number of projects (239), whereas Puducherry, Tripura and Goa have only one project activity. Many states in India do not have a single project activity towards GHG reduction. Andhra Pradesh, Chhattisgarh and West Bengal have contributed in non-renewable energy CDM projects, rather than renewable projects[15]. Projects have been registered under different methodologies. However, the maximum number of projects are under the approved methodology of small-scale projects (AMS). Year-wise and category-wise registered projects were also studied (Figure 5). Wind energy projects were always the highest in number each year. Particularly in 2012, the number of all CDM projects was highest when compared to other years. In the last two years, there has been an increase in the number of solar projects.

Important and frequently used methodologies have been explained here, in addition to the information given in Table 4. Any kind of renewable energy generation which would be connected to the national grid with maximum generation limit not exceeding 15 MW and hydro power generation with power density greater than 4 M/m^2 is considered under the AMS ID methodology. Any project which is involved in new renewable energy generation or in replacement and repair in an already installed project is considered, while projects based on the heat generation are not considered. Baseline emissions should be calculated based on the combined margin with the help of a tool to calculate emission factor. Generally for this methodology the baseline emissions are calculated by the product of exported energy to the grid with emission factor[17]. The ACM0002 methodology is almost similar to AMS ID, but generally large capacity production plants which exceed 15 MW are considered here[18]. The ACM0004 methodology is used when waste gas is utilized to generate electricity and all other aspects like baseline emissions, emission factor calculations, etc. are the same as in other methodologies with a small change when base line is calculated for captive power generation[19]. When a new natural gas-based energy production plant is constructed in a region of abundant

Table 4. Important methodology used in registered CDM projects in India under the energy industry category

Methodology	Title
ACM0002	Grid-connected electricity generation from renewable sources.
ACM0006	Consolidated methodology for electricity and heat generation from biomass.
ACM0012	Consolidated baseline methodology for GHG emission reductions from waste energy recovery projects.
ACM0013	Construction and operation of new grid-connected fossil fuel-fired power plants using a less GHG-intensive technology.
AM0029	Baseline methodology for grid-connected electricity generation plants using natural gas.
AMS I C	Thermal energy production with or without electricity.
AMS I D	Grid-connected renewable electricity generation.
AMS I F	Renewable electricity generation for captive use and mini grid.

Source: ref. 13.

availability of natural gas resources, then such projects are eligible to claim their emission reduction through the AM0029 methodology[20]. In the case of AMS IC methodology, thermal energy production with or without generation of electricity, which includes solar water heater, solar cooker and biomass energy production, is considered. For projects under this methodology, maximum production capacity of the thermal and electrical equipment should not exceed 45 and 15 MW respectively. Calculations of baseline emissions largely depend on type and efficiency of the particular project. For baseline calculations, efficiency of the plant is used for thermal energy production which replaces the fossil fuel with biomass, whereas coefficient of performance is used when identifying the baseline emission of electricity consumed by the captive plant[13,21].

A study of CDM project has been done with wind power project in Tamil Nadu. Wind electricity generators (WEGs), 5.25 MW (seven numbers of 750 kW), have been installed at Pavoorachattaram village in Tenkasi Taluk, Thirunelvelli district. The generated power has been exported to the southern gird of India. As the power generation is less than 15 MW, it qualifies to register as a small-scale CDM project. In the absence of this wind energy production, the same amount of energy would have been generated using coal-based power production which is environmentally harmful. But in the proposed wind energy, there is no GHG emission associated with it[22].

The project participant has approximately invested Rs 288 million in the installation of WEGs. The estimated energy production is 12,629 MWh per annum, which in turn will produce 11,711 CER per annum (1 CER is equal to 1 tonne of CO_2 equivalent) in the crediting period of 10 years. The electricity generated would be sold to Tamil Nadu Electricity Board (TNEB) at the rate of 2.90–3.39 INR per unit. The entire project has fulfilled its criterion as a sustainable development project by enhancing social, environment, economical, technological well-being by developing local employment, reducing GHG emissions and promoting wind energy. Approved methodology AMS lD, grid-connected renewable energy generation version 17 has been used along with appropriate tools to calculate emission factor, project and leakage emissions. Baseline has been calculated as the product of net electricity generation and its exports to TNEB, which could be measured by meters installed at each of the seven turbines with the calculated combined emission factor with standard tools[23].

Another project involves a cement manufacturing unit operating in Guntur district, Andhra Pradesh. Average annual production capacity of cement is 660,000 tonnes. During the process of cement production, waste heat is generated in the form of flue gas from the clinker cooler and rotary kiln. It has utilized the waste heat generated from the clinker and rotary kiln during the process of manufacturing cement to generate steam-based electricity for its captive use and also the excess power would feed to the southern grid. The project participant has invested approximately Rs 123.5 million to generate 9.14 million units of power per annum, which in turn produces 7766 CER per annum in the crediting period of 10 years. The National Authority of Clean Development Mechanism, India has given approval after the unit has implemented a sustainable project. Two waste heat recovery boilers and a steam turbine have been installed in the project boundary to utilize the waste heat recovery. In the absence of project activity, the unit would have to depend on coal-based energy from the grid along with captive production units based on diesel and coal[24]. AM0024 baseline methodology for GHG gas reduction through waste heat recovery and utilization for power generation at the cement plant has been utilized along with other tools to calculate baseline, project and leakage emissions. Emission reduction has been calculated[25] with combined emission factor of 0.85 tCO_2/MWh.

About 90% of the projects registered were renewable energy generation, which indicates that utilizing renewable energy sources is the best possible way to mitigate emissions from coal-fired energy industries. The renewable energy resources in the country are abundantly available as wind and solar energy. Yet the utilization of these energies was not done due to economic barriers. As the renewable energy projects have viable opportunities to get financial support from CDM, the Indian Government should particularly encourage project developers in the states which do not have participation in the CDM. From this study, the CDM programme has been proven to be a successful mechanism for mitigating GHG emissions at the lowest cost for the Indian scenario.

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Subject selection bias in animal studies

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Animal studies have always shown bias in selection of particular sex. Female subject numbers may be becoming substantial in clinical trials after law enforcement but sadly due to no such mandates, female animals are often left out. Because of multiple cited reasons male animals are still the preferred choice in the preclinical studies. The report highlights this issue and ways to overcome bias by suggesting steps that can be taken.

Several preclinical or biomedical studies have proven time over that male and female animals behave differently to drugs and devices. They show disparity in terms of safety, efficacy or subtle differences in pharmacokinetic and pharmacodynamics profiles which, if not given importance at basic research level, will amplify in clinical studies and may prove to be a waste of resources, let alone abject disaster for human health.

Realization of the fact that research with no to little female participants is egregious for science by the National Institutes of Health (NIH), USA, saw the establishment of the Office of Research on Women's Health (ORWH). The NIH Revitalization Act passed on 10 June 1993 by legislators exhorted and mandated to enrol more female participants, if not equal to male numbers, in all government control and supported phase III clinical trials. This drove change leading to increased enrolment of women in clinical studies in USA, the European Union and Australia. But no such compulsion has been made for basic biomedical research to include both sexes. Most experimental pharmacological studies show preferences for male rodents.

Biological fields and bias

From basic science to biotechnological, preclinical to translational research, all show male bias. According to an editorial in *Nature*[1], males dominated most of the animal studies as male biases were found in 8 out of 10 biological fields with ratios of male-only against female-only studies: 5.5 in neuroscience, 5 in pharmacology and 3.7 in physiology. It was also reported that 75% articles in reputed immunology journals did not indicate the sex of animals used in the study.

Reliance on existing limited knowledge

For generations researchers and scientists have only used male animals. Publications also do not have sufficient sex-related data, which may help researchers in selecting appropriate animal gender. Referees of manuscripts ignore significance of the subject's sex. Even if both sexes are found to be studied in some journal articles, they fail to perform differential data analysis. Many ostensible reasons are cited for the male bias in research: literature search and adhering to the same protocol, convenience, cost, experimental simplicity, belief that sex difference is of no major concern beyond the reproductive system – results in data from male study extrapolated error free to predict for the female population with ease, etc. The most arguable, valid and contentious reason deals with the repro-