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Strategic Prioritization of Action Plan Towards De-Carbonization and Sustainable Energy Transition for Developing Nations

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ABSTRACT

The strategic prioritization in policy synergies heterogeneous stakeholders and opportunities that facilitates developing nations to game for betterment of society in limited resources. The strategic prioritization methodology was presented to frame long and short-term actions with available resources. The theme is to develop inherently de-carbonize economies with minimum spending, efforts, adopting best practices, exploit regional potential, optimize asset efficiency, recycling/reuse, technology and innovation, etc. However, trickle down global climate change regulations require level of awareness for regional energy dynamics, politics, bureaucratic structure, training and education, infrastructural weaknesses, financial barriers, etc. Several conflicting, non-measurable and inconsistency in policies destroy efforts towards net carbon zero and hindering de-carbonizing objectives in the developing world. No doubt, societal factors and their interest's influences political systems engaged in energy transition policymaking, implementation and enforcement. Therefore, it's time to organize energy transition efforts/planning in a way that it has minimum financial impact and keep developing economies on momentum. The article highlights sustainable policy instruments, initiatives, best practices, opportunities, innovation areas and identify stating steps those will inherently lead climate change ambitious targets of de-carburization in developing economies with minimum financial investment.

1. INTRODUCTION

Energy transition journey towards de-carbonization gaining momentum and strategic prioritization of action plan for developing nation's is a challenge. The target is to limit global average temperature increase at preferably 1.5°C above preindustrial levels, as concluded by the United Nations (UN) in Paris Agreement [1]. Inter-Governmental Panel on Climate Change (IPCC) has anticipated the continues CO_2 emissions will potentially rise sea level causing multiple destructions in eco-systems; increase droughts, species extinction, absolute poverty levels, life expectancy, rising oceans acid levels, declining crop productivity, increases in malnutrition, infectious diseases spread, etc. [2]. Basis according to IPCC, total cumulative carbon dioxide (CO_2) emissions in end 2017 was 2230 $GtCO_2$ and it left the margin of 420 $GtCO_2$ (January 2018) for average global temperature rise to 1.5°C until 2050 [3]. IPCC links energy transitions with demand and sets broader sustainability context keeping earth as a natural system, with the 17 UN Sustainability Development Goals (SDGs) [4]. Complete understanding of planet energy system is still in progress as it is a constituent of multiple systems/layers having no full operational independence, size of energy producing or consuming, distribution size (regional or local grids), emergent nature, and evolutionary development. The gap between observed emissions and proposed reductions as per agreed climate objectives are keep increasing.

The technologies desired for energy transition is still in progress and 2050 target date is probably over optimistic. The climate change is a fact, where completely greener future is a challenge as pose an imminent existential crisis and its urgent solution is shared responsibility. Therefore, sensible policies, sustainable technological solutions, prioritization, etc. to tackle energy transition and de-carbonization will allows weaker economies to contribute and survive in better shape. One of the major objections on adoptability or deployment of disruptive acceleration in this transition is associated costs. For the policy prioritization review, IPCC, International Renewable Energy Agency (IRENA), and International Energy Agency (IEA) open source information were analyzed with developing nation's individual action plans.

The core of agenda is to reduce GHG emissions. Therefore, understanding about the carbon flow in energy system is

important, and it is distinguished by carbon categories and sources. Before digging deep in action plans and discussing options/policies to prioritize actions, let's overview GHG emission classifications and sectors contributing in energy system's carbon footprint (see Figure 1). These sectors are pillars of social system (where size presented in Figure 1 is fictive and illustrative only) and one can classify itself by defining its boundaries. The focus was given in this article to help developing nation to strategically prioritize action plan with qualitative approach. Therefore, the quantified information such as size of the sector and its contribution in GHG emissions were not discussed, as these numbers may vary with time for each nation.

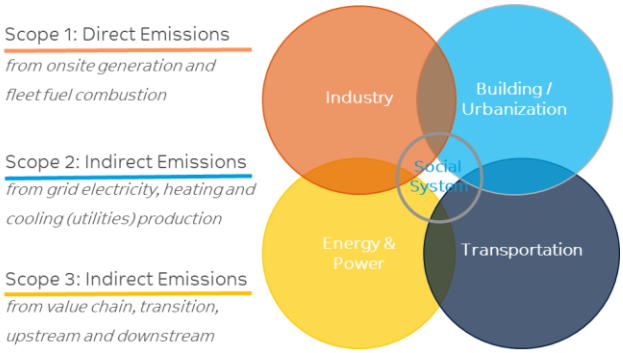

Figure 1. Topology of emissions scope and energy sectors

One of the important questions, why to start focus on developing nations? As developing nations are most populated and resources consumption centers. Resource allocation and financial spending is also a challenge. Therefore, setting realistic targets (national action plan) and strategic prioritization is the key to achieve de-carbonization, reduction in avoidable emissions and balancing unavoidable emissions in an equivalent amount of CO_2. Exhaustive emissions from each system accounted in various scope classification from one to three. Most of the direct emissions from operations fall in Scope 1 and Scope 2, accounted ~5% and remaining ~95% emissions are from supply chain activities. Commonly used term "Net zero" means that the amount of greenhouse gases (GHG) produced is balanced with removed GHG in said boundaries. Oceans and land (are natural sinks biosphere) remove ~50% of GHG produced. In practice, the current level of 412 ppm (1ppm equivalent to 1.8 mg/m^3) of CO_2 in atmosphere needs to reduce to 350ppm, which required complete stopping of fossil fuels [5]. European countries are pioneering in policy making or developing plausible pathways toward net zero carbon. Netherlands announced emission free cars by 2030, Germany planned for coal power plants phase out by 2038, Portugal almost achieved 100% electricity production from wind and hydro, Switzerland stimulate renewable energies, energy efficiency and phase out of nuclear power plants, and Denmark declare 100% renewable energy use in heating, electricity and transport by 2050 [5].

A novel addition of circular economy concept in industrial sector is itself restorative or regenerative by innovation, changing consumer with user. The optimal portfolio options of de-carbonization depends on variety of factors and its design feedstock/product suitable for biosphere with no 'end-of-life' and 'waste generation' concept. Renewable energy use is also promoted in complete production cycle. In the process industry, these concepts create clear-cut value generation opportunities. Figure 2 demonstrates general amplification, starting from feedstock (1) and catalyst (2) used in process will be greener, substituted, consumed or recycled; utilities and energy requirements (3) of process meet via greener route to control CO_2 emission; within boundary of industry (4) or circle, minimizing energy intensity, enhancing energy efficiency and improving process of conversion to more environmentally sustainable; appropriately use of residual energy and waste (5); product and profit (6) were also defined as reusable, consumable and recyclable with minimum CO_2 footprint and extends product longevity. The beauty of circling concept refers to increasing number of consecutive cycles (whether reuse, re-manufacturing, material cycling, etc.) and/or time for each cycle. The cascaded use diversify circular concept across whole value chain and reduce new materials substitution.

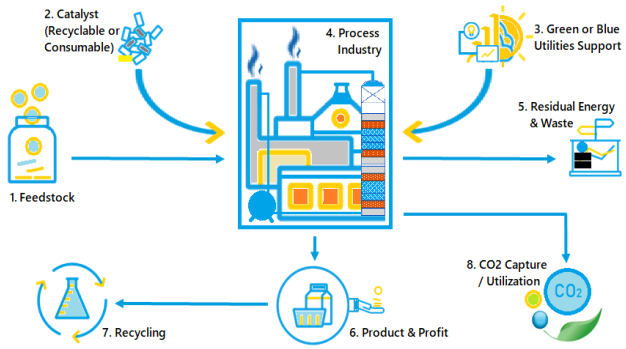

Figure 2. Energy reduction and circular economy strategies

Transformation toward renewable energy and sustainable carbon-neutral technologies to limit/reduce GHG emissions has been gained attention. In addition to it, various guidelines and actions were devised without proper synchronization, that made it puzzle and overall success reported is questioned owing to climate changes dashboard. Extensive GHG emission reduction measures are taken by various developing countries, while penetration barriers of renewable energy technologies still promoting fossil fuels. Therefore, it's a shared responsibility to play role in capacity for sustainable energy transition and de-carbonization [1]. Building energy transition and de-carbonization [1]. Building foundations of fair tangible energy policies and enthusiasm for developing nations and environmental justice is itself a challenge [6]. Therefore, knowledge sharing and easy excess of advanced technologies from developed nations to developing can bridge the gap faster. As a consequence, governments of developing nations also devised strategy, setting long and short term goals, aiming limitations to preindustrial emissions. Two approaches are commonly regarded to achieve this goal are carbon feedstock mitigation (by enhancing renewable resources share, energy efficiency, etc.) and reinforcement of carbon sinks (either naturally through afforestation/reforestation, or artificially using CCUS technology).

IRENA did extensive work to model energy development scenarios based on planned policies and propose ambitious climate-resilient roadmap [7]. The energy transition roadmap regularly updated with developments or adopting low-carbon technologies as a baseline for comparing progress and identifying investments. It serves as guideline to governments on their ongoing energy plans and targets/commitments under Paris Agreement. It has been further forecasted that renewable energy options in heating and transport sectors could reduce two-thirds of emissions [7-9]. An equally important goal is to reduce poverty because most environmental problems cannot

be solved until community is ready to bear adoptability cost [10-14]. In this complex scenario, decorated policies were presented with vision statements in Intended Nationally Determined Contribution (INDC), whereas policy prioritization for developing nation's need more professional and practical approach. This article divides national policy instrument to reach their energy transition and de-carbonization targets with respect to level of investment (tiers). Aligning polices with tiers will save efforts, resources, expenditures and time to reach the targets of de-carbonization. Start tackling various aspects, such as imaginary implicated governance, energy integration, erratic power supply, level of technology knows how, upgradation of existing technologies, framework to enable sustainability, politics, etc. This manuscript further helps to outline policies prioritization and developing methodology for actions and investments without affecting socio-economic momentum of developing nations.

2. METHODOLOGY

The UN has outlined roadmap with SDG's, where timeline spanning short, medium and long-term goals. More specific polices for a particular country explicitly outlined in INDC. While multiple gaps/challenges based on techno-social infrastructure has been observed for developing nations, needs action prioritization. Theme behind methodology of strategic prioritization of action plan in sustainable energy transition and de-carbonization has considered many aspects, starting focus on financial position to inherent national potential with "no regrets" adaptation, assert efficiency, effective disaster management and more strictness for upcoming energy intensive installations, uninterrupted energy supply, cost of energy and time. Priority options in policy for implementation starts with low hanging fruit and negative costs projects such as energy efficiency enhancement or integration opportunities. Further down the road commitments by each nation with sector's and stakeholder/actors identification (as illustrated in Figure 3), with realistic and measurable targets is part of methodology considerations as transition take time and investment.

The de-carbonization policy can't be driven faster without economic interest, where engineering estimation of benefits and costs of inaction (economic effects of climate change) need more clarity for each nation. Quantifying measurable effects of climate change that incorporates risk, mitigation with technological change, economic costs of adaptation, costs of major catastrophic events, non-CO_2 GHG's and sinks, and recent abatement technologies, etc. Framework assessment of risks and uncertainties will be an accompanying policy toolbox within low carbon transition pathways [14]. To achieve de- carbonization, massive scale carbon technologies are required, alongside energy efficiency and behavioral change measures. No doubt, opportunities exist, but associated with unseen risks; while said change cannot executed at the expense of moving economies, productivity, demand and living standard. Therefore, detailed techno-economic evaluation of each policy action will be reviewed with de-carbonization objectives and integrated synergies. Staying away from the "valley of death" policy makers must enable technology framework (computational methods) to accelerate climate-proof investments. It's possible to pin point, more efficiently and diversified portfolio of energy sources, i.e. to make less responsive energy sources more responsive, reduce carbon impact of poorly performing sources, lower investment, etc. Recognition of all emission reduction initiatives falling in scope 1, 2 and 3 are equally important to meet de-carbonization.

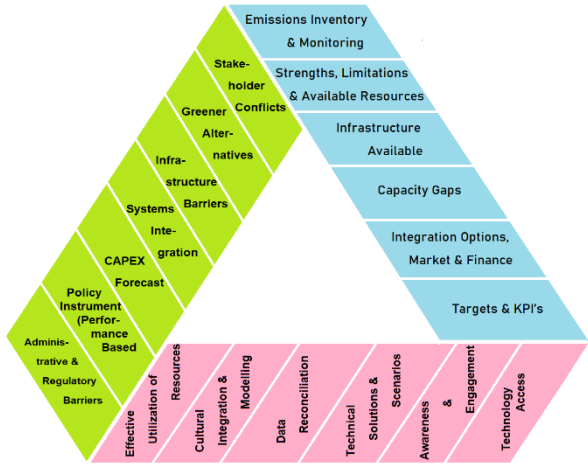

Figure 3. Stakeholder/actors for methodology considerations

Table 1. Identification of SWOT for developing and under-developing nations [14, 15]

Strengths	Weaknesses	Opportunity	Threats
Geographic position	Bureaucratic processes	Regional integration	Corruption
Political stability	Level of awareness	Electricity demands	Land ownership
Economic stability	Sense of urgency	Improve energy efficiency	Education
Renewable feedstock	High capital investment cost	Promo case studies	Fossil fuel dominance
Renewable energy Implementation	Sense of responsibility	Awareness of climate change	Conflicting policies
Research Institutions and institutional supports	Little attention to off-grid systems	International support funding	Erratic climatic conditions
Public and private investment	Low electricity tariffs	Improve assert efficiency	Environmental impacts and food security
Generalize emissions calculation and reporting	Dearth of commercialization of scientific research	Price decline in renewable energy and rebates	Wheeling arrangements, supply and feed-in-tariffs
Defined targets of each sector	Environmental and ecological protection	Renewable manufacturing support	Energy markets
Centralized monitoring and targets	Equity and justice	Society, culture, and behaviour	Legal requirements
Unified dashboard	Finance & infrastructure	Value chain improvement	Technology access
Cheap workforce	High energy demand	Land availability	Utility cost

Every developing country has its own energy dynamics with strengths, weaknesses, opportunities and threats (SWOT), as tabulated in Table 1 [14, 15]. Strengths represent available resources and those reduce profitability are weaknesses. To model nation energy outlook, possible questions are: available/unlockable renewable energy resources, policy favors, level of expertise, technology availability, operational ease, interest of investors, jobs creation, scales of opportunity, available financing and profits, how much climate impact it will create compared to fossil fuels, demand and infrastructure needs, etc. This study discussed gaps and challenges first to specifying technical and social factors with respect to emission profiles. Secondly, define prioritization strategy outlines, limitations, prospectus, capacity/technology support. Third, time planning with respect to financial stability. Fourth, integrated simulation of facts needs to cross-checked potential outcome with national model and define actions. Carbon-free technologies in many sectors does not exist or not mature enough, therefore, CAPEX and OPEX estimation is near to impossible and various subsidies desired to reduce threat of competitiveness by adopting said enormous changes. Devising de-carbonization and energy transition policies requires extensive understanding of socio-economic structure and resources demography of the region. Therefore, policy enabling framework must classified in number of categories, such as societal, cultural, political, ecological protection, energy market and demand, responsible authorities for policy enforcement, legal requirements, diverse range of stakeholder objectives, infrastructure, economic (finance), impact or clash of interests, synergetic effects, etc. [15].

At the same time major issue in most the developing and under-developing economies is to deploy dedicated resources in their budget. Policies can also confront with new challenges and potential to manage such consequences is expansive. For example, some nation's still investing in coal-fired power plants and impede decarburization, and extreme is that some even doing it on imported coal [16, 17]. If still coal-based power plants are announced, or planned, or under construction, national efforts will never reach net carbon zero. Prioritization of strategies inhibits development of carbon-intensive energy systems for an ambitious de-carbonization path. Therefore, prioritization got attention to gear up developing economies for de-carbonization, starting for policy development where minimum or no CAPEX (Capital Expenditures) from stakeholders is involved. After getting confidence on benefits from such policies they get motivated to start inviting in coming milestones as per priority roadmap.

After SWOT analysis and stakeholders identification, thematic tier methodology for policy to lead de-carbonization actions were devised. Fictional theme is to identify options, deploy cheaper solutions, their impact from every sector and emission demography. For instance, in transportation sector a target to limit cars with less than 80g CO_2 per kilometer (either by hybrid or electrification) by certain year and at same time integrate with electricity production emission at backend. Therefore, policy prioritization will help nations to achieve economy-wide emission goals with CAPEX, whereas some individual actions may not contribute significantly. Complementarities range of policy instruments and strategies impacted by multiple barriers and vary in different geographies due to differences in above discussed contextual factors. The efforts and policies to address de-carbonization cannot be generalized that may lead to business-as-usual or overload financially. The methodology revealed an integrated approach to strategic prioritizing in developing countries for achieving goals of net carbon zero. Authors feel the sense of urgency to develop this methodology to grip low hanging fruit that is manageable with minimum investment or even by best practice. This prioritization in policy will enhance the actions effectiveness and outcome. However, the dynamics of energy is complex and integrated, therefore, identifying variables and simplifying equation will make the de-carbonization target easier to achieve in every geography.

3. STRATEGIC PRIORITIZATION

Strategic prioritization tier approach is developed using above described methodology for policy in energy transition and de-carbonization. The schematic Figure 4 demonstrates fictive emissions reduction classification into four tiers with business as usual and reduction potential using different policy tiers. Tiers were prioritized starting from no or lower capex/investment to intensive investments, therefore, combined with a qualitative cost curve display emission reduction cost. Numbers displayed are purely illustrative to demonstrate cost and effect of prioritization for energy transition and de-carbonization.

An alarming highlight is that need attention on actions and obstacles in policies of zero cost, and their implementations are still on shelf. These policy tiers are not limited to following; Tier Zero (start with immediate effect and no or minimum investment), Tier I (to be completed by 2030 with minimum investment), Tier II (to be completed by 2040 with technology shift measures), and Tier III (to be completed by 2050, capturing all emissions by force). A detailed overview of SWOT as discussed in Table 1 with respect to developing and under –developing nations for future viability of system and this section linked these with tiers. The prioritization approach (discussed in broader prospectus) will be robust and extremely effective tool to formulate SMART policy by developing clarity and filling gaps in action plans [16]. The strategic prioritization of national action plan enables governments to effectively implement, enhanced decisions and deploy resources on de-carbonization commitment with minimum capital burden. This approach of strategic prioritization is further trickle down with Tier's philosophy in measurable policy instruments are discussed below.

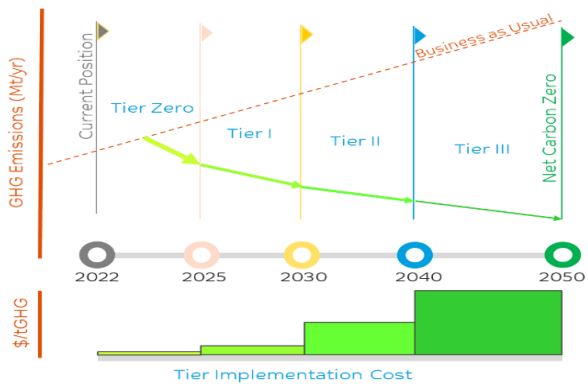

Figure 4. Fictive summary of tier methodology for strategic prioritization of policy actions to achieve de-carbonization

3.1 Tier zero

It is an emergency policy and/or actions need to start implementing with immediate effect. The philosophy behind this tier is to control emissions with inherent potential, without signification financial investment. This tier is more about the correctness of policies, actions, gaps and/or conflicting synergies, such as putting efforts on reducing emission and in other means producing emissions in same sector. Tier zero should be extremely strict for new installations to achieve de-carbonization targets. This will mitigate emissions up to 40-60%, while actions are not limited to the list below, as directional.

- ✓ *Green Initiatives / Effective Land Utilization:* Population load is comparatively higher in developing nation's poses adverse effects on many issues. Governments did not give much attentions to control rate of urbanization on agricultural/fertile land. Most of cities were developed in beginning, where water and food were available, or in other words on agricultural land. Urban density is well established and proposed dense cities as sustainable. Or new cites and industrial sites may be planned on arid or less productive land. Most mountainous/tourist lands were vastly urbanized, need to restore natural environment. Moreover, empirical evidence shows that efforts for green initiatives has lower value addition, if cities extensions on agricultural land continues. Forestry contributions in overall emissions reduction is well known, as one tree absorb ~22 kg of CO_2/year. Gradual increase in deforestation owing to number of reasons in developing nations, where policy strengthening regulations are desired. Therefore, expected benefit from sink effects will not fruitful until complete stop of deforestation [18]. Governments should support/educate formers to enhance agri-production per unit land with slogan grow more, by introducing technologies, more organic production or crop verities, better irrigation solution, etc. At the same time, individuals were promoted to grow useful leaves/vegetables using hydroponic forming technology (kitchen gardens or roof top gardens) to meet his daily requirements. Policymakers should provide an easy and affordable access to community for smart agri-technologies. It is desirable to strengthen entire food value chain to attain objective of achieving net zero emissions by tier I.
- ✓ *Administration and Ad-hoc Decisions:* Centralize energy transition and de-carbonization administration, monitoring, policy makers, all governing bodies to align efforts with one vision. Efficient emissions monitoring and reporting systems from air, water and land, need to established sophisticated database, that help in mapping policy flaws, capital investments and stimulation economic growth with application of feasible technologies. In most of the developing countries ad-hoc policies are common practice in energy sector (such as inaction on vital issues, particularly on energy pricing) compared to professionally planned/adherence actions. There is need to say no to conflicting policies and practices. Asserts are underutilized in developing nations due to consistent-policies, corruption, mismanagement, security, technology, capacity, investment, etc. Train locals in particular sector, developing in-house technology/know how for greener scope of core business. As per UN definition of emission classifications, each individual sub-sector has to fully eliminate emissions from their scope. Complicated situation may arise for cross border taxation for refinery and petrochemical products, where emissions vary with product scope and lifecycle. In such scenarios a balanced policy for CO_2 anti-dumping tax or legitimacies is needed for developing countries. This could be in form of offer to producer to invest in CO_2 mitigation under corporate responsibility at end user area.
- ✓ *De-Globalization:* Territorial sustainability in all regards is primary aspect to support global priorities. If territory is producing raw material for any product and consumed same and it's manufactured in another territory! Policy makers should highlight this situation and plan to address this by developing its feasibility to manufacture in-house.
- ✓ *Water Resources and Disaster Management:* Unconventional water resources such as recycled/rain/flood water harvesting, synergistic distribution and superior innovative water management legislation are open options. Large water reservoirs are most environmentally friendly as they produce greener electricity and storage. Planning on large and small dams is integrated with smarter irrigation and green electricity, and this potential need to developed maximum by tier II. Nations should have detailed disaster management plan to solve issues inherently and emergency response mechanism. For example, floods management by walled rivers passing from cities; continues removal of sand/mud from rivers for filling low-level areas, cementation, drainage in urban areas to manage urban flooding, etc.
- ✓ *Energy Conversions and Efficiency:* Authorities/bodies are made time to time in developing countries for promoting, regulating and monitoring efficiencies. There is a huge gab in capacity and their scope is somehow limited to labeling, need upgradation and centralized to synchronized policy efforts. Implement and define criteria for energy-consuming items, processes, support governments in provision of incentives BAT (Best Available Technology) adaptation and foster investments. Such as all lightings should be LED's, with auto sensors for switching on/off.
- ✓ *Circular Economy:* Encourage circular economy initiatives (material recycling, waste management, improved material processing efficiency) and practices. Water, metals, renewable resources, leftovers, and materials were reused, recycled and reduced in general. Deeper emissions reductions, which are difficult to accomplish, can be facilitated by lifestyle modifications.
- ✓ *Power Sector and Renewable energy:* Complete de-carbonization of power sector need to be planned maximum by tier II, by developing dams, solar, wind, biomass/waste, and other renewable options such as nuclear. Resource mapping serve as facilitator for fossil fuel subsidies, potential, investment and obstacles in renewable energy developments [19]. Strict laws should prohibit construction or planning of new coal-fired power plants, and coal capacity should phase out as it reaches end of its useful life. Align renewable heat and efficiency strategies to take advantage of synergies.
- ✓ *Transportation Sector:* In continuation with BAT discussion, converting upcoming two to three wheels vehicles on electricity and set highest level of fuel efficiency for upcoming vehicles. One of the gray areas observed under current circumstances, most of

developing nations are purchasing production units for producing inefficient vehicles those will absolute soon; this should be stopped by policy. Minimum vehicle emission standards should be established. Electric vehicles should be prioritized for city access, such as development of stepwise upgradation to electric busses and trains. In this tier integrated road map to fully de-carbonize transport sector maximum by end of tier II need to be developed. Socio-technical perspective on policies of fossil fuel subsidies rather than carbon tax, are one of the main barriers for decarburization and energy transition.

- ✓ *Buildings:* Establishing building codes and standards for energy efficiency, includes all appliances, heating/cooling equipment's, lighting, etc. Building control authorities and town planes develop uniform policies, such as smart houses and wider roads, high construction to greenery ratio, maximum use of sun light, ventilation, sustainable low-weight construction material, better insulations, improve control over energy usage equipment's, etc. Policies should dictate strict implementation in upcoming construction activities. Plan in this tier for new smart cities, integrated industrial sites, infrastructure requirements and development milestone.
- ✓ *Industrial Sector:* For developing nations, it is challenging to upgrade, small and heavy industry as sectoral priority. The most important message of Tier Zero, is to restrict upcoming energy intensive procurement/importing/buying/installations/developments in this sector that did not meet energy and carbon intensity criteria. Plan with inherently safer investment for future industry, rather that achieving short term economic goals and facing de-carbonization issues in longer run. Encourage enterprises to engage in direct investment for self-generation and benchmark to employ best available technology (BAT). One of the examples is marble/stone industry in developing nations where blasting technology is still in practice and about 90% of material loosed. Progressively for new installations choose/develop integrated sites to share feedstock, energy and resources.
- ✓ *Research Planning:* Focus on national strength, plan for individual sub-sectorial research/expertise and catalyze near-term implementation projects. One of the key game changers is to find novel route to add value to existing raw material and process. Work on small captive disruptive ideas, such as waste heat utilization form kitchen (cooking) at site, etc. Plan for developing advanced technology pilot projects to train and expedite learning.

3.2 Tier I

This tier classified as minimum effort or minimum capex and provide basis for further coordinated approach for facilitation in medium-term concerns. Long term infrastructure should also be planned to support de-carbonization activities till 2050 and stepwise investment accordingly.

- ➢ *Smart Agriculture and Irrigation System:* Urbanization on agri-land completely stopped by policy, as stated in Tier Zero. In this tier, addressing vulnerabilities within agriculture requires improved irrigation infrastructure and smart agricultural reforms by focus digitalization. Governments have to complete this change maximum by this tier by providing modern equipment's and infrastructure. Forest and soil acts as natural sink of carbon boosting sequestration [17].
- ➢ *Administration and Financing:* Governments should improve awareness, seriousness, trained employees and community by engaging subject matter experts. To facilitate synergies consistent policies, smooth institutional approvals with transparency obligations and robust centralized monitoring system and enhanced delivery. Close co-operation and attractive financing between government and private sectors is key to boost de-carbonization and energy transformation. Integrated policies to increased demand for renewables, for example, through corporate clean energy procurement, investment in the implementation of EV charging infrastructure, and so on.
- ➢ *Water Resource Management:* Investment focus on integrated water reservoirs are the best option for green energy and continuous supply. Both smaller and large size options should explore simultaneously. Smaller hydropower project are not threaten by scale if water flown to naturally shaped reservoir. In this tier, rivers passages form urban areas should cemented with solid boundaries, maintain their width and proper depth. While this exercise is capital and time intensive, therefore, planned in smaller chunks of most affected areas on priority.
- ➢ *Energy Conversions and Governance:* Energy conservation norm set in tier zero will continuously practice and reflects in behavior. Conservation benchmark keep updated for new installations based on BAT. Policy should enforce, practiced in all sectors and facilitated by infrastructure. Investments in this regard will mobilize and attracted by involving all stakeholders.
- ➢ *Circular Economy:* As developing nation's imports, e.g. petrochemical products, vehicles or engines, etc. need to be address on life cycle of product by choosing recyclable materials. Product end-to-end energy consumption and emissions need to be evaluated and planned for its tax collection. Circular economy strategies can result in significant reductions in energy demand and emissions.
- ➢ *De-Globalization Investment:* As planed and identified opportunities in Tier Zero, government's has to facilitate local and foreign investors to set-up their companies with end-to-end business solutions.
- ➢ *Energy Portfolio and Systems:* Phasing-out existing captive power facilities, should compensate with full potential of renewable energy by inviting stakeholders for installing hydro-dams, solar panel farms and wind turbines. Although potential may not exist for certain area, even then it is highly recommended that at least pilot unit should installed for training and know how. Renewable energy technologies are highly capital investment, therefore better to be localized to overcome this threat. Renewable energy linked to low feed-in tariffs, off-grid systems should promote for remote areas and net-metering provide additional opportunities. Biogas, bio-methane and waste hydrogen (H_2) could be a potential low-carbon fuel, promoted by policy and planned for infrastructure requirements adopting smart gas grids. Start upgrading area with smart electricity grids (micro-grids) with latest technologies includes digital elements. Support regulatory/pricing measures such as right to create and sell electricity, tariff regulation, and grid-arrival rules to shift energy customers to prosumers.

- *Transportation Sector:* Modernize railways and efficient domestic public transport systems. Plan should not be a bourdon on economy, therefore, it's recommendable to upgrade in various steps, start with smaller railway track where traffic load is high, or route that can managed by small number of busses, deploy low-emissions short distance loaders, etc. To boost renewable competitiveness in transportation, eliminate fossil fuel subsidies, introduce carbon pricing and encourage biofuels production. Work on optimizing travel network, in-house electrical vehicle design and manufacturing, and acquire fuels from local markets to reduce transportation.
- *Infrastructure and Urbanization:* Developing nations needs sustainable infrastructure that promote culture of renewable energy, efficiency initiatives, inherently greener system, adoption of best available technology, and public involvement. Defining path for sustainable infrastructure, emphasis in tier I is to implement inherently greener society, with costly retrofit design, less construction timeline, high energy efficiency, smart lighting, heating and cooling, etc. Sustainability with expanded population relies on urban metabolism, devour most of resources, where new issues of environmental management ere expected [1, 14]. According to the Brand's Law, urban density is conclusive empirical evidence to sustainability/resource-efficient and intensive integrated infrastructural plan is highly desirable.
- *Industry De-carbonization:* For developing nations to date policy/roadmap/milestones for reducing industrial GHG intensity and complete de-carbonization is a challenge. Therefore, in tier I, recommendation is to focus on process optimization and efficiency enhancement to level of best practice in known art, by fuel switching, energy integration, recycling, waste minimization, etc. Developing nations relying largely on SME's (small and medium enterprises) driven by private stakeholders where deep de-carbonization remains formidable, due to lack of compelling co-benefits, old processes, competitiveness pressure, finances, resources, technology access and available fuel, etc. Therefore, governments should start helping SME's to reduce their carbon leakage on priority. One of common example is old bricks formation system using coal, emitting full carbon to atmosphere and having extremely poor heat management.
- *Research and Development (R&D):* In this tier develop R&D in cutting-edge technologies needed to reach energy ambitions. Develop knowledge, expertise and train local manpower for supporting low carbon hydrogen production growth is possible through electrolysis science, carbon capture and storage (CCS) and other renewables. It is critical to encourage systemic R&D by establishing a regulatory environment that allows digitalization of smarter energy systems (e.g. artificial intelligence, block chain, internet of things, etc.).

3.3 Tier II

This tier starts from 2030 and it's important to achieve targets of previous tiers before starting tier II. More strict pledges and policies are desired to promote de-carbonized activities of scope 3 based on clear standards, methodologies, aligned definitions for claiming energy transition impact. Emphasis remains not to focus cost intensive and high risk areas contributing. Therefore in this tier, policy mandate/instrument should force action to complete decarbonize production of electricity, improved efficiency, waste minimization, improve natural carbon sinks (forest management) with desired food productivity and enhance soils framework, etc. The purpose of this article is not to discuss multi-indicator analysis for CO_2 emissions estimation while concentrating on policy prioritization.

- *Green Initiatives / Agriculture / Effective Land Utilization:* These policies were set and implemented at their maximum in tier zero and I. Only room for adaptation of state of the art technologies to enhance agricultural productivity in Tier II.
- *Administration and Governance:* Each component of governance system should work properly with one vision to accelerate de-carbonization and manage, without any negligence in policy decisions. Interim policy updating with respect to economic and financial issues poped need to address professionally to keep nation on de-carbonization track.
- *Water Resource Management:* Integrated water reservoir projects for electricity and smart irrigation need to be completed in this tier. This will address most of energy and transportation sector emissions.
- *Energy Efficiency and Circular Economy:* Revision made as desired to set norms continuously based on technology advancements and practice. Extend circular economy to every daily life product, especially imports and attract investors.
- *Renewable Energy Portfolio:* In general, electricity system will roughly grow to double by 2050 owing to demand increase in various sectors. Nuclear power and advance offshore wind are reliable low-carbon electricity options, wherever applicable. On similar line, support to unleash potential for smaller or cascaded motor design/manufacturing, as advance wind turbines generate enough electricity with a single rotation.
- *Modern Transport:* Policy acceleration to zero emission transportation should be visible, under green transport strategy. In this tire focus on private vehicles share taken by public transport to accelerate sustainable transition by investing in rail, zero-emission buses, electrical cars and infrastructure, etc. Establish manufacturing of hybrid and electric vehicles that can drive with zero carbon from tailpipe with extensive supporting integrated infrastructure and sustainable fuels [20]. Shipping and aviation sectors exemptions on fuel tax should be lifted, carbon price would be implemented, hydrogen ferry concept, high percentage blends or drop-in biofuels, etc. to unlock numerous opportunities.
- *Infrastructure and Urbanization:* Agile policy plan was made in tier zero for this sector, need to optimize/rethink strategy, and implement disruptive ideas with BAT in this Tier. Regardless of building age, standards envelope with cost and integration to ensure heat, ventilation and energy harvesting (natural light usage, overall energy efficiency). Smart building envelopes contribute greatly to improve energy performance as well as indoor quality and comfort. Heating and cooling are one of the largest final energy consumption areas using fossil fuels, where renewables can change picture. Innovative materials usage in construction helps in improving energy resource efficiency, durability and cost reduction.
- *Shaping Industry:* This tier focus shift from conventional process upgradation to shape industry with novel concepts

like hydrogen as clean fuel source. Conventional hydrogen production route form methane is one of the most energy intensive process, therefore, install pilot projects using various routes to green hydrogen. CCS is an effective and readily available mitigation option that is sometimes underestimated where no other cost effective solution is available [21]. The de-fossilization of energy systems is most powerful tool in de-carbonization, where renewable hydrogen is the key. De-carbonizing LNG by focus on lifecycle emissions, supply chain require robust emission monitoring and reporting, that is currently not there, such as carbon-neutral cargo. CO_2 can be used as a feedstock, like the nature, in plants. There are certain technologies, such as Methanation (Sabatier process-catalytic conversion of CO_2 by reacting H_2 to produce methane at moderate temperatures 250-350℃ and pressures 20-25 bars at nickel or cobalt catalyst), CO_2-to-diesel or Jet-fuel (produced via Fischer–Tropsch synthesis), CO_2-to-methanol, etc. [22]. Remove existing roadblocks and encourage adoption of low-carbon heating technologies: Solar thermal heating, replace fossil fuel-based feedstock, contemporary bioenergy, renewable hydrogen and heat pumps are all viable options. The major carbon reduction lever in cement industry is lowering clinker-to-cement ratio, as it is biggest sources of CO_2 emission in scope 1. Innovative cements with new binders, calcined clay will gradually replace traditional mineral components such as slag or fly-ash. Oxy-fuel combustion uses oxygen instead of air to produce pure carbon dioxide, which is easy to sequestrate in cement industry. Similarly, steel manufacturing is emitting anthropogenic CO_2 during iron oxide reduction with coke in blast furnace and some additional CO_2 emitted during conversion of iron to steel. Steel and concrete prices are artificially low in part because firms are permitted to dump CO_2 and with carbon taxes could be skyrocket. Similarly, raw pulp can be decreased by using recycled fiber and crossroads of bulk natural CO_2 absorption processes (forests) were affected.

- *Technology and Innovation:* Developing nations have history of knowledge and cultures, therefore, they need to scientifically focus on "what they are good at", and need to strengthen complete supply chain of technology from feedstock to market. They should invest or scale-up pilot projects on dearth of innovation commercialization in their core business, sustainability and circular economy.

3.4 Tier III

Tier III starts from 2040 and to accomplish vision of complete de-carbonization. Nations should pursue efforts that address the vulnerability of sectors influencing climate change by intensive actions. Despite expected emissions reduction with cohesive measures of previous tiers, in this tier all-practical solutions were planned to achieve net carbon zero. Investment and collaboration to several technologically mature concepts were tackled in this tier, such as low-carbon hydrogen generation processes, utilization of CO_2 and biomass as feedstock, electrification of chemical operations, etc. [22-25]. The collaborative/joint ventures initiatives and consolidation of success in implementation of prioritized technologies will focused and social inclusion that leaves no one behind (as outlined in the Paris Agreement article 4.19) [1]. Prioritization in policy and advance planning implications in developing countries can save huge investment with brilliant outcome on reduced carbon emissions.

- Geothermal Energy: In this tier developing nations needs to tap other available energy options such as geothermal energy. Due to technological barriers, risks and heavy investment, recommended as last option [26-28].
- Advanced Transportation: In several long-haul transportation, aviation, and shipping, need to address for complete net carbon zero. Technologically less developed nations need to focus on renewable fuels (e.g. biofuels) and its supply with infrastructure facilities. In this tier only technology advancements to be addressed such as super-fast maglev, hyperloop, vac-trains.
- *Modern Industry:* In this tier modernize industry to net-zero by technology investment. State of the art CCUS adaptation need to be installed where inherent technology solution will not address emissions. Novel workability is underway to reduce cost of CO_2 capturing from air/flue gas using membranes, solid oxide fuel cell, geological storage of CO_2 such as fertilizing ocean ecosystem, etc. It is potential to replace fossil fuel, produce green, pink, olive, yellow and blue hydrogen, and improve its safe transportation. Integral roadmap for green hydrogen strategy tailored to H_2 ecosystem, whereas cascaded hydrogen generator option is preferable. Ammonia (NH_3) is key for making fertilizers and fuel as hydrogen storage, produced conventionally from fossil natural gas as hydrogen feedstock, this can be avoided making hydrogen from electrolyzed water. Ferrous metals production consumed huge energy in comparison with non-ferrous metals, as having high embedded energy in electropositive metals (Al, Mg, etc.). Therefore, it is a tradeoff in substituting energy-rich embedded light metals for vehicles. Oil and gas sector de-carbonization wave for energy efficient operation should plan out of BAT in this tier.
- *Innovation Commercialization:* Out of the box innovation is desirable to improve technology-built cost trajectories for renewable energy supply chain from production to end consumption. [29, 30]. Otherwise, distortive market effects or other inequalities prevent an increased integration of new market players.

4. DISCUSSION

Analysis of SWOT and prioritization of actions, addresses the question how to quantify de-carbonization success based on extending technical and financial situation in developing. Adaptation of tiers into economic appraisal, national periodization of actions are extremely important with their integrated cross-sectoral synergies. Most of the policy led actions listed in tier zero changes the emission dashboard of each nation, that is by corrective measures and best practices, where no significant investment is required. Implementing the prioritization methodology tier zero will relieve financial pressure on national investment in de-carbonization and improve their emissions outlook. Government/policymakers should plan integrated SWOT and stakeholder's interest analysis/brain storming sessions with experts to frame tier zero policy/actions for each sector.

A variety of complementary polices appear to be green in particular scope but insufficient as adding emissions to other scope, therefore, innovative breakthrough technologies in

recycling/reuse are highly desirable [1-4]. Standing support of scientific team for policy makers to capture change benefits and highlight conflicting aspects of various technologies is part of story. In the absence of a well-thought-out transition strategy, transparency in actions, deep de-carbonization of industry could be enormously disruptive and costly, necessitating comprehensive simulation or review at tier zero. Successive tiers are cost intensive as proceed with time and may encounter technological limitations or challenges in developing nation.

Developing nations may ask as UNFCCC Paris Agreement under CBDR (common but differentiated responsibilities) rule, the de-carbonization potential will be realized through collective efforts both financial and technical assistance [1, 2, 4]. Emerging industrial policy has become heart of actions while vary in across national contexts. Integrated framework to explore the relationship between de-carbonization policy instruments and empirical planning implementations has overlapped with innovation policy. Presented roadmap to net zero will play vital role in helping developing countries to identify multiple scenarios and priorities actions to achieve de-carbonization goals.

5. SUMMARY

The article emphasises on strategic prioritization of developing nation's actions to faster deployment on de-carbonization to address common goal i.e. to limit global warming to 1.5℃ above pre-industrial levels. Irrespective of technological and financial challenges, developing world has huge potential to contribute by corrective and appropriate policies. It's further outlined how polices can divide into different tiers to drive actions on de-carbonization, considering complex emergence of diverse set of actors, such as technology limitations, influential individuals, investors, government, society, etc. Autharities/policymakers should carefully choose reliable data to construct actions that suits unique national circumstances while maintaining investor's confidence. For example, at the moment renewable energy share in developing nations is relatively infant and mobilization require policy support. Another important aspect that existing policies could not stop upcoming emissions or subsequent factors.

A systematic tier methodology has been presented to address prioritize policies in a way to start with corrective measures or best practices. Tier zero serves as instrumental guidelines to prepare house in order without capital spending. To start with low hanging fruit, and optimize compatibility; where authorities should stop new energy intensive installations/manufacturing/products/imports not meeting de-carbonization targets or those going to be obsolete. Focus on eco-technology deployment to unlock available energy resources, assert efficiency and energy conservation [30]. Tier I and II set stepwise investment plan with careful coordination between sectors: power, building, transportation and industry. Key outlook of tier I is energy conservation, low carbon power and circular economy. Tier II is a cross-model continued expansion of activities with of affordability assessment for portfolio optimization of complete renewable power, transportation and buildings. Tier III enabling framework of complete eradication wheeling arrangements and need policy intervention to force expansive decisions, BAT, and investment. Investment to commercialize innovative solutions or technology imports were also pursued in this tier. The discussed strategic prioritization of action plan for achieving de-carbonization will expedite energy transformation in developing countries and help in endure energy scarcity.

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