INDUSTRIAL ENERGY TRANSITIONS

World over, we are passing through a significant energy transition and are witnessing the industrial revolution like never before. Sustainability, Green Initiatives and environmentally conscious approach is the key to a circular economy. The current pandemic has been a catalyst to accelerating these areas for many reasons; from the environment to social to geopolitical to the simple realisation, nature needs more respect. The underlying theme in the current transition period is a better appreciation of our future generation's responsibility and care towards the planet and its resources.

While the economic cycles are becoming shorter, the basic demands of developed-developing nations are normalising, and the gap is diminishing. The so-called equalisation is also exponentially increasing the negative impact of industrial growth and its future sustainability.

Revisit Lifecycle Energy Demand:

Energy and resources drive growth. The demand for resources is also undergoing a shift, almost as if new elements from the periodic table are now needed, which were rare and reserved for exotic use only a few decades ago. Nevertheless, the most significant change is being felt on the energy mix regarding its quantity and quality. It is quite strange that while the world has utilised the high energy density sources such as coal and oil, we are now compelled to seek low energy and intermittent energy sources like solar, wind and geothermal. We are now finding means of storage, transmission and distribution of the energy generated from these sources to meet similar metrics and continuity as those of high energy density sources. However, this rule's exception is nuclear energy - both fusion and fission, which have too high energy densities.

Though it is essential to find solutions concerning the 'Energy Density and Continuity' challenge, it is also equally imperative to think about the overall energy footprint regarding the materials used in mitigating the challenges. While Hydrogen has one of the highest energy densities in the order of 120-150 GJ/tonne (Nuclear energy is the exception as it has many times higher energy density than Hydrogen), its low volumetric density is a matter of concern which results in a low energy per unit volume, hence Hydrogen storage is an issue. Similarly, the solar photovoltaic cells are an attractive source for renewable power generation, but it requires a large land quantum. Same is also applicable for bio-fuels initiating concerns over food vs fuel.

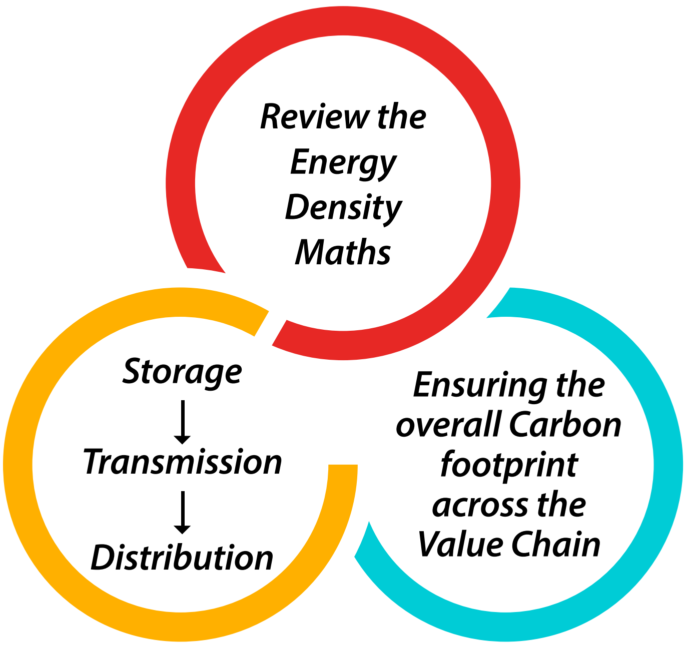
It is essential to evaluate the energy requirements of the complete product lifecycle. For example, Aluminium is a lighter material than steel and, hence, possibly better for automotive applications, but can this reason be considered a green and sustainable solution? The energy required to produce a tonne of Aluminium (approx. 300 GJ/ton) is almost six times compared to

Iron/Steel (approx. 50 GJ/ton). Similarly, while Solar PV is default and preferred choice to replace thermal power plants, the energy required to produce one tonne of electronic-grade silicon (approx. 7600 GJ/ton) is almost 15 times compared to iron in making of turbines.

The initial energy transition journey may have to adopt renewable sources; for example, green Hydrogen by water electrolysis route can utilise electricity generated from renewable sources. But for being ***"GREEN"*** needs a holistic perspective in the long term seeking sustainable and low carbon energy sources. Extending the logic further, the cost of pumped/battery storage and its energy maths in terms of material and losses at each stage of its flow – from generation to storage to conversion needs to be accounted. Hence, energy transitions must consider a holistic life cycle management to account for energy needs from the cradle to the grave.

Energy Transition Approach:

Energy transition will systematically require the following phases.



Value chain in the energy transition process is a bit complex. One needs to anticipate the shift in the value chain that may occur either due to ongoing industrial revolution or due to expected exponential maturity in technology that may change the value-chain landscape. Hence, it is necessary to adopt a strategy to interconnect the various value chains, considering the current one's anticipated changes.

Finally, we need to justify any transition with financials and business case, keeping in mind the volatility and shorter economic cycles demanding faster returns (gone are the days of 20 years payback periods) else incentives, policies, penalties, and offsets may fail to provide long term sustainable usage. However, these ingredients must be a catalyst to accelerate the energy transition in the initial stages. Technology development (linear or rapid) and maturity phase requires policy support to kick start the energy transitions, e.g. cost of bioethanol manufacturing is presently 30-40% higher than the price at which ethanol is being sold in the market. Green Hydrogen currently costs approx three times than the blue Hydrogen. So, policy support to incentivise green Hydrogen or bioethanol may help accelerate the transitions.

Recommended Approach for Energy Transition:

From the industry perspective and professional consultants' lenses, a holistic approach to clients across O&G, Metals, Mining, Infra, Power, etc. must be provided. We need to keep these factors in mind and have a framework that helps clients achieve their vision and roadmap for the energy transition to a low carbon future or low carbon energy source.

Changes are indeed the most exciting playgrounds for visionaries, scientists, engineers and pioneers – but they take time; for example, it took the wood to Coal to Oil-based, and then gas energy sources almost 80-100 years each time to gain a 50% mix. Solar/wind/nuclear are much recent and still in single or lower double % regarding overall energy composition.

It would be pertinent to note that this energy transition will be much faster and rapid and may take maybe 30 years due to the exponential pace of technological innovation and advancement, maturity and a more global collaborative effort unlike the past when it was more siloed and concentrated. While energy transition may start in respective value chains, it requires a cross value-chain approach across industries to reap enhanced and overall benefit based on uniqueness.

- While modernisation is inevitable and maybe linear or rapid due to disruptive technologies, the focus will be on integrating the technological advancements with the old technology to ensure low carbon footprint, including gas balance, steam balance, and energy balance.

- Energy transition initiatives may reduce material requirement and complexity (from 10,000 moving parts and BOM and supply chains to say 100-500 parts – more electrical and less mechanical) and be cost-effective in the Automobile industry. Similar drivers shall be identified in other sectors such as Power, Process, Steel, Infra, etc.
- A specific focus is required on visibility/ consideration of the carbon footprint across the value chain, including the manufacturing/ processing equipment and operations with a view on Capex/Opex, i.e. Total Cost of ownership and operations.
- While utilisation of waste or recycled material is a process, it needs to be integrated across value-chains to enhance recycling and improve carbon footprint by optimising the waste footprint.
- A robust modular and repeatable framework may be adopted to assess each system/process shop/ plant - and this applies across all industries, but in varied proportions and may involve different timelines and phases.

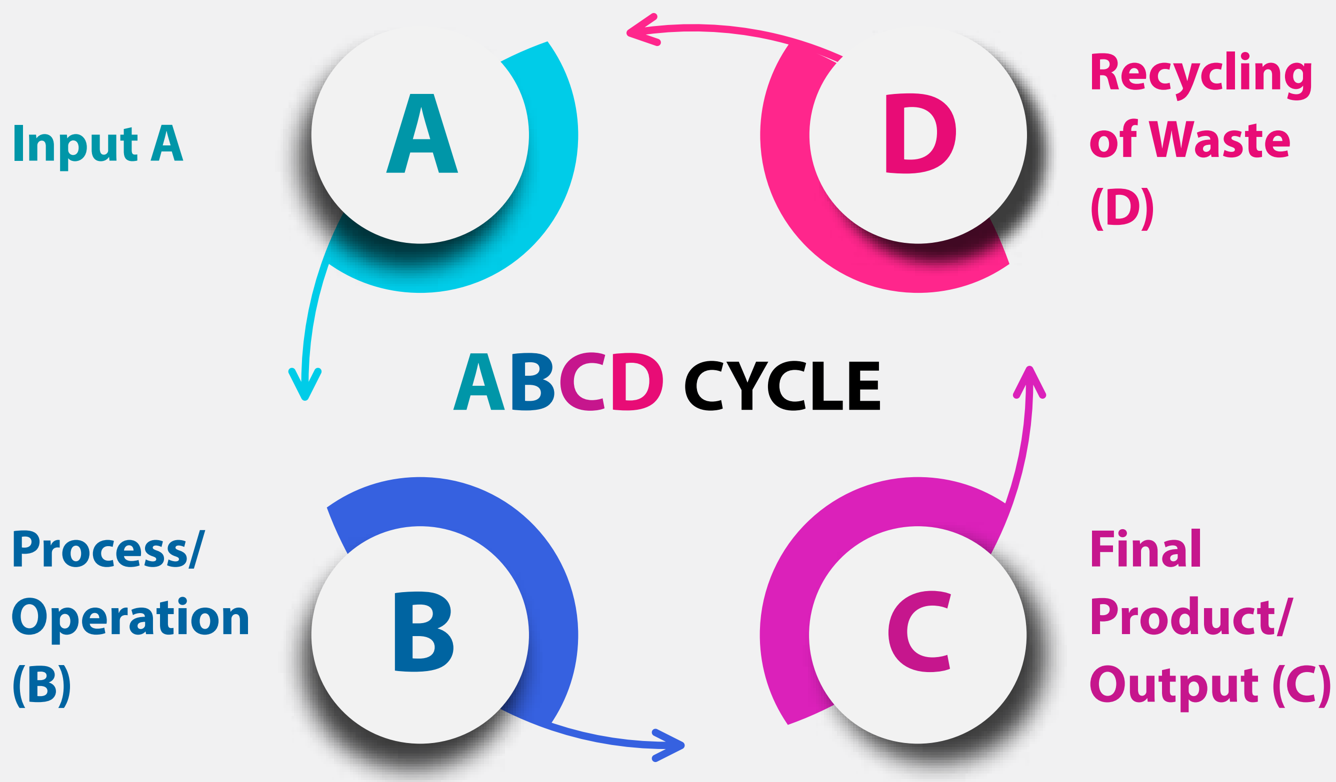
Simple ABCD Model for Energy Transition:

We visualise the entire energy transition process as a simple ABCD cycle. Typically, this model depicts the plant operations in a simplified way. Raw materials (***A*** of the ABCD Model) are processed using specific technologies or operations (***B*** of the ABCD Model) to make desired products (***C*** of the ABCD Model), and the value chain is completed after recycling (***D*** the ABCD Model) the product back to the process.

Some of the energy transition themes (given below) that can go through the ABCD Cycle need to be reviewed holistically, as explained earlier, to develop a strong business case.

A: Look for alternate feedstocks to make the same product. Ensure that the alternate feedstock consumes lesser energy during its manufacture/lifecycle. Prefer ***'Green Feedstock'*** with true ***GREEN*** footprint pre and post-production. Use research and innovation to promote energy transitions by locating newer and affordable green synthesis pathways.

It is essential to evaluate energy density maths of the



alternate source and its production. The per capita energy (in terms of land, people or weight etc.) needs careful evaluation while selecting the energy transition techniques.

B: Improvements in operational efficiencies and energy optimisation opportunities should be considered, especially using cutting-edge digital technologies to improve efficiency under varying loads vs constant peak loads.

Pull and Push strategy: Ability to seamlessly change the production volume and mix and maintain high efficiencies in both Pull and Push Strategy.

Peak Capacity operations vs Flexibilisation, i.e. stable & efficient operating level ensures the optimum cost of the operation

Inter-Connected / Enhanced Transmission & Distribution / Hybrid Grid Infrastructure

C: Better quality of products which can last longer. Energy transitions to reduce the demand for the product by making long-lasting and superior quality products.

D: Less Wastage (Recycling) driven by both efficiencies and circularity mindset, i.e. optimum utilisation of resources

Concluding Remarks:

Energy transition road map will be unique to every organisation. It requires prioritisation across the different areas of operations within the organisation, aligned with transition roadmap of an organisation keeping existing laboratory scale efforts and their technology readiness (TRL) levels so that a parallel program can be drawn for the future.

Industry partnerships or Consortiums or conglomerate may have to be sought for a collaborated effort focusing on internal efficiencies and agility to develop a strong business case and justify the cost. A startup, innovation ecosystem with the help of pilots and experimentations and support from the government, academia and industry may accelerate the energy transition.

Our approach in this journey shall be to work with clients, academic institutions and industry partners to have a holistic view of the industry/sector energy map. The transition needs to ensure that any efficiency and optimisation or flexibilisation (as regards production volume and product mix) are enabled by rewiring the enterprise and connecting the legacy (for asset sweating) with the digitalisation. Digitalisation needs a parallel business case and shall be an integral part of Energy transition, else without the digital glue, integration and rewiring will be suboptimal.

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