Develop a CAD Model to Purify Air from Truck Exhaust

Under:

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Abstract

- The prime motive of this project is to develop a CAD model of a system that purifies the exhaust gases from heavy-duty vehicles, essentially trucks, which are the largest sources of harmful emissions leading to air pollution.
- Also, to provide a sustainable-energy substitute for the roughly two million fossil-fuel-powered trucks sold per year globally. [1]
- In order to reduce the greenhouse emissions in the transportation sector, one can electrify the vehicle, switch to biofuel, or capture and store them on board. In our model, we have chosen to employ the capture method.

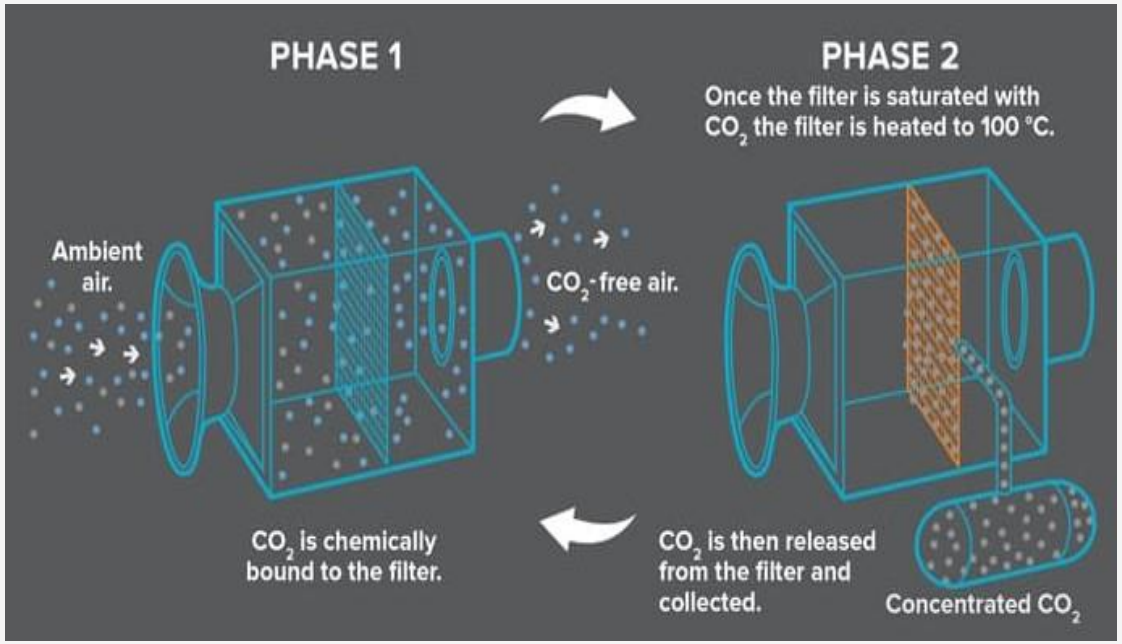
One may ask why not switch to an electric alternative?

- We may, but only if it is capable to. A truck should be efficient, feasible and affordable. It is used for commercial purposes, which is made to carry heavy loads to far destinations. When these are not met, the concept is dropped.
- Also, they are really hard to electrify, just because they are so huge, and the time taken to recharge it is high as compared to that of refueling it. That is where this concept comes into play.
- Hence, a typical diesel-powered commercial truck would be an ideal target vehicle. Heavy-duty trucks like tractor trailers, container trucks, prime movers, etc., come under this category.

Principle

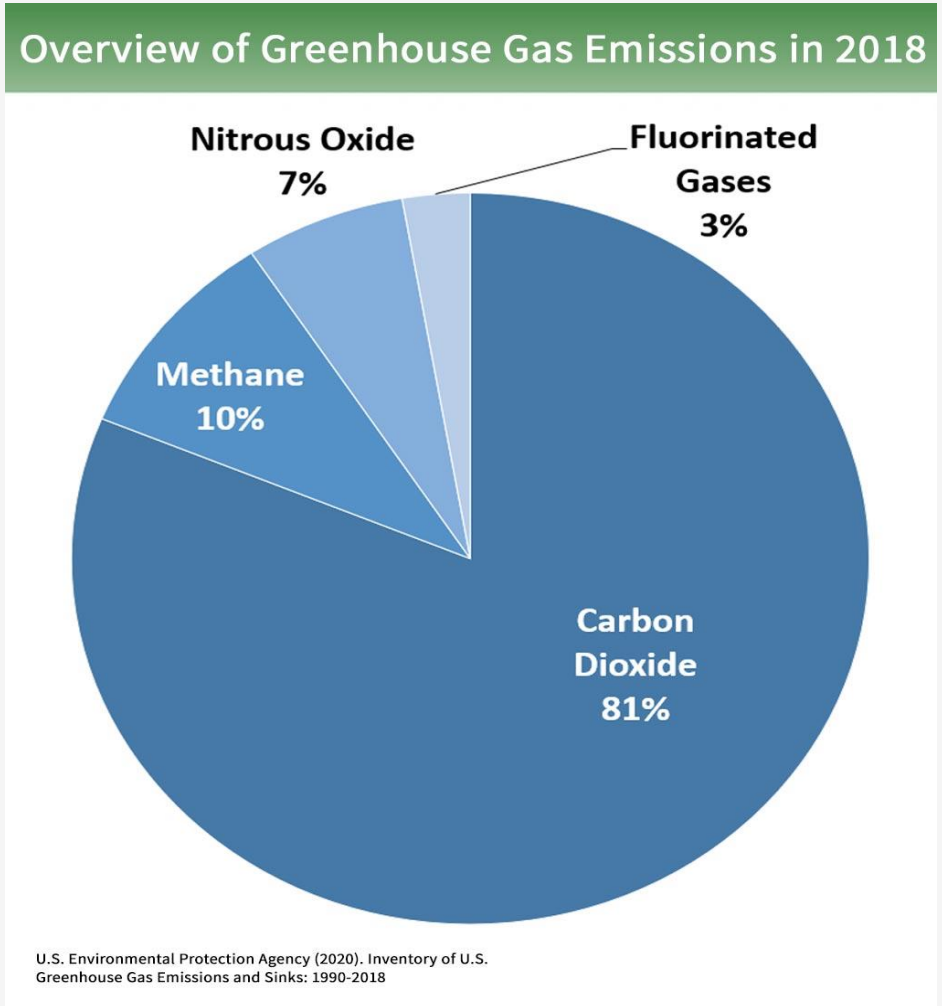
- *Direct Air Capture (DAC)* is the technique used in this process.
- The most common technique for this process relies on chemical scrubbers (*adsorbent*) with very high surface area contact to absorb the carbon dioxide from the flue gases.
- A scrubber is basically a porous membrane which has strong affinity to CO_2.

What is DAC?



Get rid of CO_2

- Gases that trap heat in the atmosphere are called *greenhouse gases*. These emissions cause the *'greenhouse effect'* and in-turn climate change. CO_2 is the main greenhouse gas produced by motor vehicles.
- Studies show, CO_2 alone accounts for 81% of all the greenhouse emissions. This can be witnessed from the chart beside.
- So, our main aim is, removal of CO_2, and release a CO_2 free air into the atmosphere.



Implementation

- The whole process takes place within a capsule, placed above the driver's cabin. Apart from that, there's a storage tank or a collector, connected to the capsule via the turbo-system.
- Air is drawn into the capsule, where a modular system of collectors absorbs the incoming gases. Inside the collectors, CO_2 binds chemically to a filter.
- Once the filter is saturated, the turbo-compressor starts working to liquefy it and release the CO_2 solvent, which is stored in the collector.
- Later the Carbonate solvent is separated from the capture solution and sent for recycling.

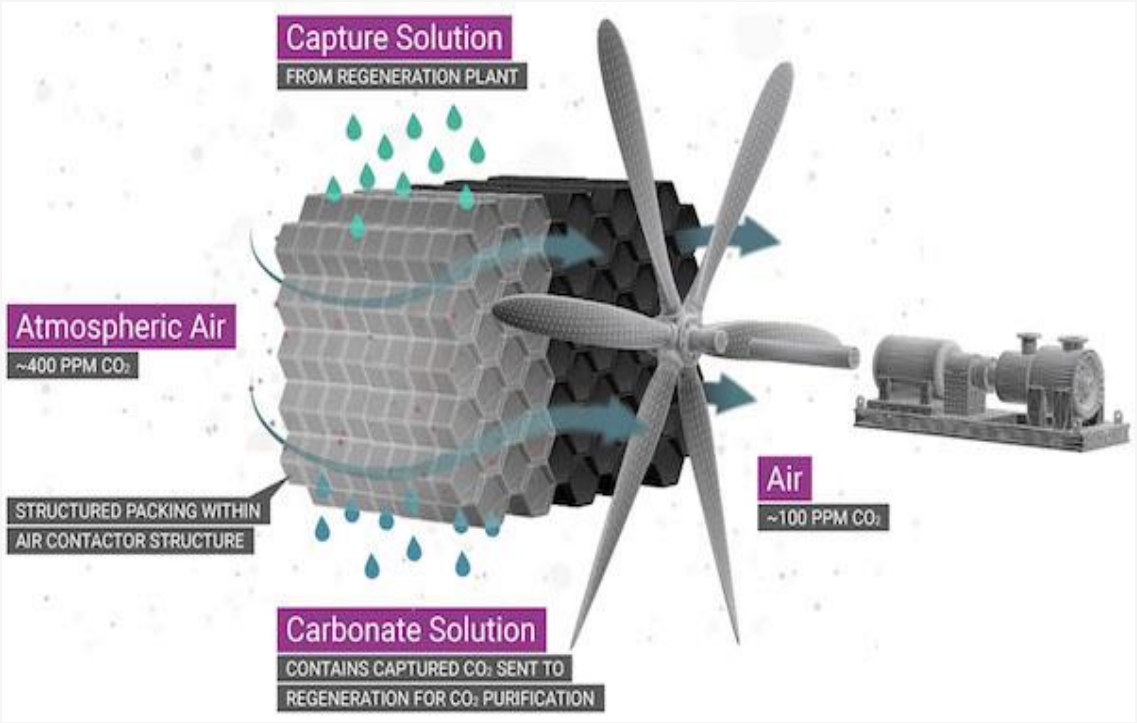
ESSENTIAL COMPONENTS OF THE MODEL

- A ***separator line*** is connected to the outlet of the existing Diesel Particulate filter or a catalytic converter, via the exhaust stack.

- The DPF removes diesel particulate matter or soot from the exhaust gas. Majority of exhaust gases are filtered before sending in.

- *Some of the main components-*

- ***Porous membrane***- This is the key component of the whole setup. The air flows in the same direction as of the incoming exhaust gases.



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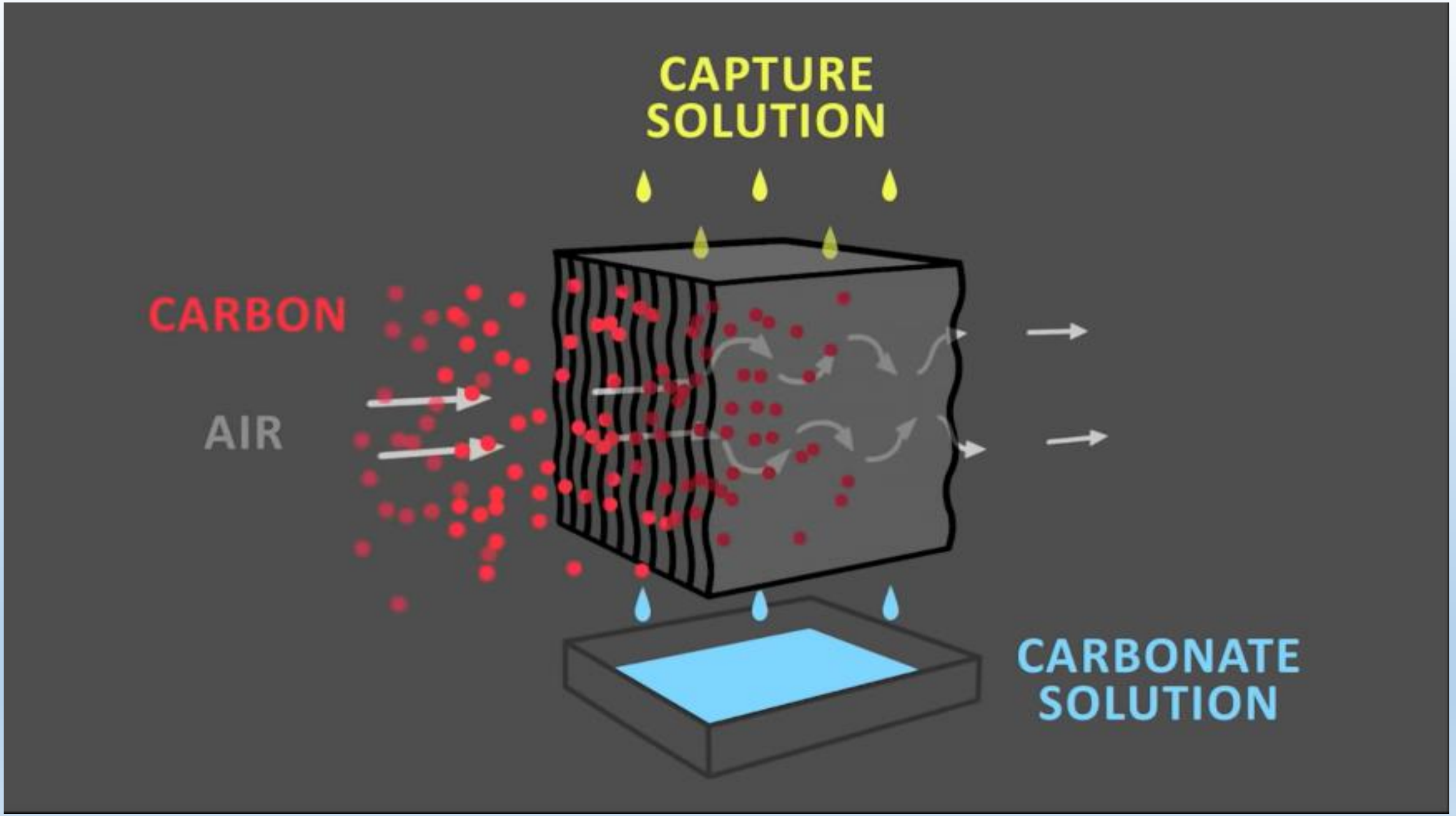
- Now we supply our CO2 absorbent liquid to the top, so it flows down with gravity. Where they meet is right in the middle of the device that is filled with all these tightly corrugated PVC sheets, used as a *filter,* which absorbs the incoming exhaust gases.
- The CO_2 laden gas will go through this porous material.
- ***Capture solution*** — CO_2 absorbent liquid (*aqueous amine solution*).
- To selectively capture carbon dioxide from the exhaust gases, one would usually use aqueous amine solutions as a liquid solvent. This capture solution has a strong affinity to CO_2.
- Every single surface inside is wetted with a CO_2 absorbing solution.


CAPTURE SOLUTION
CARBON
AIR
CARBONATE SOLUTION

Contd.

- Air containing CO_2 flows over these surfaces, and when CO_2 molecules encounter the liquid, they're converted to carbonate solution.
- The geometry of the packing material ensures that it’s much of a liquid as possible as exposed to the passing air. It also disturbs the flow creating turbulence, so most of the air streaming through, actually makes contact, with the solution.
- The net result, carbon dioxide is trapped in solution for further processing.

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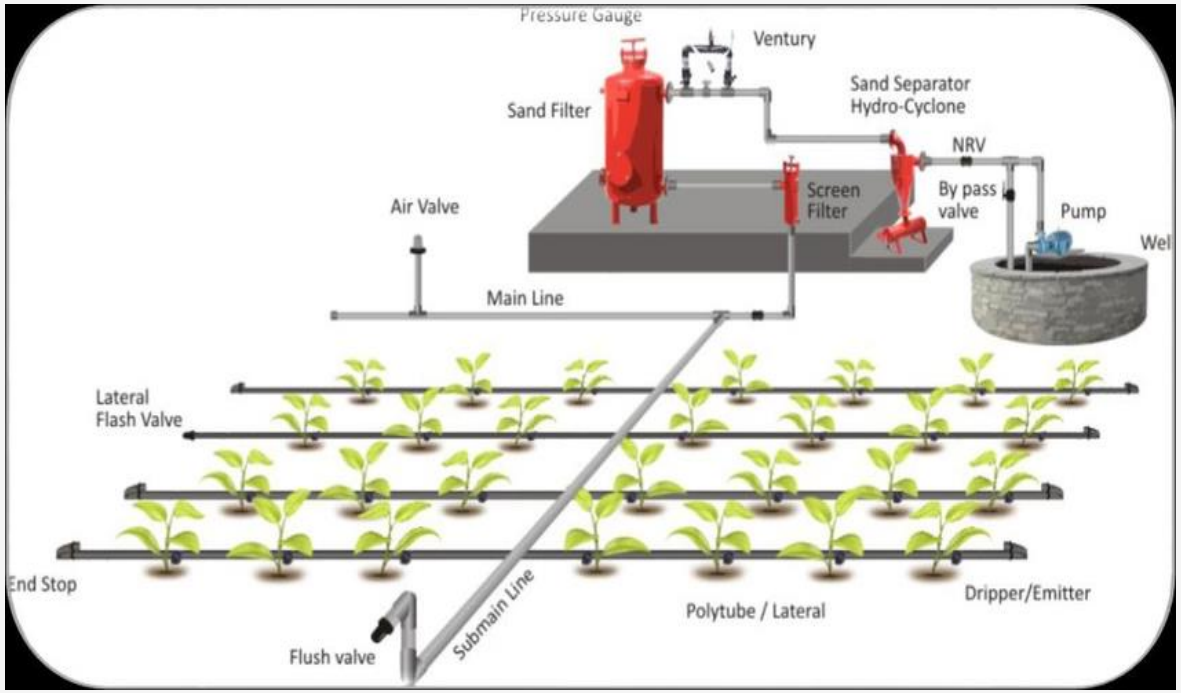
- ***Drip Line Technique-*** This technique works on gravity. We have employed this to drip the capture solution on to the filter.

- This method is inspired from the ***drip-irrigation system,*** where water is dripped to the roots of the plants, either from above the soil surface or buried below the surface.

- It has the potential to save the capture solution by allowing it to drip slowly to the top of our porous filter, because of the fine holes that come with it.



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- ***Turbo-compressor***

- Once the material is saturated with CO_2, a high-speed turbo-compressor, runs to compress the extracted CO_2 and turn it into a liquid.

- This results the pure CO_2 to be extracted from it.

- For efficiency, the turbo can be connected to the transmission line or the drive train.

- Also, it can use the waste heat of the exhaust gases of the engine to liquefy the captured CO_2.

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- ***Collector***-
- Captured CO_2 mixed with the capture solution is transferred to the collector which is then sent for further processing.
- It is basically a storage for the concentrated CO_2.
- ***Fan***-
- This is another essential component in the whole setup.
- A fan or ventilator system is placed at the outlet of the model. The fan pulls the air through the contactor. It creates suction, which draws-in the incoming air very rapidly.

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- ***Carbonate solution containing CO_2, is sent to regeneration for CO_2 purification*** —
- The liquefied CO_2 (*carbonate solvent*) is then delivered to service station where it is turned into conventional fuel using Renewable energy. The research shows that using 1 kg of conventional fuel could produce 3 kg of liquid CO_2.
- And the conversion does not involve any energy penalty. Only 10% of emissions can't be recycled.
- If it's designed properly and is functioning in ideal conditions, we can capture 80-90% of all CO_2 emissions. Once we've reached the capacity, we can use steam, hot gas or vacuum pressure and then regenerate our material so we can repeat that cycle over and over again.
- This process uses the Carbon Engineering techniques to recycle the CO_2 from its carbonate solvent.

Advantages

- *Ability to retrofit*- The advantage of this system is that, unlike electric or hydrogen-based ones, it can be retrofitted to existing trucks in order to neutralize their impact in terms of carbon emissions.
- It's done in scale to the trunk space of a modern-day truck which would be an ideal target vehicle to fit the setup.
- Entire setup can be mounted over the driver’s cabin, or else over the sleeper cab above the storage compartment.
- Most modern trucks come with flexible space options, so, availability of space is not an issue.
- Though there is only a slight variation in the air drag by placing the setup on the top, it can be minimized by installing a wind deflector in front of it.

Target Trucks

Most commonly available truck variants in terms of model design, are shown beside —

A classic truck which is suitable for our model is shown below.

Future Scope and Difficulties faced

- ***Future Scope***-

- Apart from its advantages, the potential for this concept is huge, given the impact of transport sector on climate change.

- ***Difficulties encountered***-

- Due to limited material options in the software, there is a compromise on weight. Hence, tried making some adjustments in this regard, like nearest alternatives. However, it is possible to make adaptations during production.

- Selecting the right CAD tool, given, number of alternatives available based on usability, ease of access and the time taken for modelling. Finally, opted for Solid Edge.

Cost

- ***Estimated cost of the model***-

- It would cost between €60–€90 per ton of carbon dioxide captured. Due to some current advancements and ongoing research in the field, the costs would decline to €35–€50 ($40-$57). [2]

Thank you!

Any Questions?