PSA Nitrogen Generator:

To manufacture 50 tonne of ammonia per day, 13.8 kmol/hr of nitrogen is needed. Hence, From Alibaba, we found that for a PSA nitrogen generator with output capacity around this range, costs $27,000 per set.

<https://www.alibaba.com/product-detail/95-99-9995-high-purity-Pressure_60787826987.html?spm=a2700.galleryofferlist.0.0.757e6190nOuZyY&bypass=true&fbclid=IwAR05f6CqnqFWebnMkDbC7JpRq0RstxN_PNVRGSExn_w5eeP4FgAgLFF6Q28>

This paper (<https://www.osti.gov/servlets/purl/797810/>) has costing info for packed towers and it gives a similar value for the price (~25,000 ish per tower).

Cost of labor:

To calculate the cost of labor, first we need to count the number of equipment. We have eight heat exchangers, two reactors, two absorption towers, and two absorbers, a total of 16 equipment which needs to be supervised by operators. Hence, . Then, the total of operators are needed year-round.  From the Bureau of Labor statistics (2018), the average annual wage for a chemical plant and system operator is $61570/yr. Hence, the total labor cost is .

Utility Cost (with electricity at $0.02/kW, calculated by CAPCOST):

$795,000/year (for one module)

$4,770,000/year (for all six modules)

Raw materials cost (assuming air is free and we’re using DI water):

$5847/year (for one module)

$35,082/year (for all six modules)

Waste stream treatment cost:

* Stream 5 (water stream from mist/water filter): will be recycled and used for use in other parts of process so no need to treat
* Stream 7 (remaining air components): can release into atmosphere, don’t need to treat
* Stream 14 (oxygen gas): can be released into atmosphere since it’s just oxygen with some water vapor
* Stream 28 (purge stream): components include water, nitrogen, hydrogen gas, and minute amounts of ammonia. Most likely needs to be treated. Vapor phase
* Stream 33 (ammonia waste): needs to be treated. Vapor phase

Table 8.3 in book (only for liquid and solid phase)

A screenshot of a cell phone

Description automatically generated

**When categorizing hazardous waste, the EPA breaks it down by four characteristics:**

* ignitability, or something flammable.
* corrosivity, or something that can rust or decompose.
* reactivity, or something explosive.
* toxicity, or something poisonous.

Ammonia is corrosive waste (<http://www.learn.niu.edu/tech432/new%20documents/Anhydrous_Ammonia_MSDS.pdf>) <- very useful for health & safety later on.

**Hydrogen gas** is highly flammable and will burn in air in concentrations between 4% and 75% by volume. **Hydrogen** is not **toxic**, but in its pure form is a chemical asphyxiant. **Hydrogen gas** leaking into air may spontaneously ignite. <https://ehrs.upenn.edu/health-safety/lab-safety/chemical-hygiene-plan/fact-sheets/fact-sheet-hydrogen-gas-use-anaerobic>

In stream 28, hydrogen accounts 67.5% by volume so this stream is highly flammable.

* Waste type: Flammable waste

In stream 33, hydrogen accounts 6.75% by volume therefore the gas is flammable.

* Waste type: Flammable and corrosive waste
* We're gonna scrub this stream and send it to wastewater treatment

Some costs of waste treatment pg 51 and 53 (seems to be liquid): <https://inis.iaea.org/collection/NCLCollectionStore/_Public/26/051/26051017.pdf>