Climate tech
9.7 Gt / 19%
Food and Ag
4.2 Gt
Animal and livestock farms
Biogas capture
Regenerative aquaculture
Cattle feed additives
Manure digestion
Alternative protein/dairy
Plant-based milk
Plant-based meat
Cultivated meat
3.3 Gt
Land use
Nature-based carbon solutions
Soil carbon measurement
Regen farming
Farm monitoring
Compact farming
Vertical farming
Hydroponics
3.7 Gt
Crop production
New "climate" crops (drought resistant, emissions capture)
Crop sensors
n-fertilizer usage
0.2 Gt
Automated farm equipment
The food/ag innovation world has grown signficantly over the last few years, headlined by alternative protein companies like Beyond Meat and Impossible Burger. As our food systems are critical to both our climate problems and human health problems, it's no wonder why so many impact and VC dollars have been put to work around this area. The challenges for agtech or foodtech startups is that grow cycles are usually long and can be seasonal, making it difficult to iterate quickly on new technologies. Customers also can be mom-and-pop, technology-averse, and/or extremely cost-driven, which can make selling new innovation an uphill battle.
8.2 Gt / 16%
Travel and Transport
0.41 Gt
Buses
Electric buses
CNG buses
Hydrogen buses
For buses, the jury is still out on which technology (hydrogen, electric, or even CNG) will take most of the market share. Bus routes vary significantly in terms of length, grade, and operating environment - and the combination of all of these variables will determine which "fuel" choice is best. Buses have the advantage of traveling set routes and refueling at set stations, which means availability of fueling stations is not an issue.
3.3 Gt
Passenger vehicles
EVs
Autonomy
Battery improvements
New fueling stations
Hydrogen vehicles
Nat gas fuel cell vehicles
Electric vehicles are the dominant technology in passenger vehicles. Most of the technology improvements in the EV space is concentrated around autonomy and battery improvements. Fueling station deployment is a big driver for increasing adoption. Other passenger vehicles like hydrogen and CNG face an even steeper uphill battle but may find more niche customer bases where range is of particular concern.
1.8 Gt
Heavy duty trucks
Hydrogen trucks
Electric trucks
Drive train retrofits
Hybrid trucks
Power train retrofits
As the second largest category of emissions in the travel cateogry, trucking is a major source of contention in the hydrogen vs. electric battle. Due to the large capital cost associated with a new truck and its relatively long lifespan compared to passenger vehicles, retrofits are a more viable avenue to increasing adoption.
0.825 Gt
Ships and maritime travel
New AUVs
Ammonia fuel cell ship
Portside fueling
Engine de-pollutants
Shipping is a tough sector to decarbonize. Vessels are usually large and routes take a long time to complete, lengthening the potential iteration cycle for new innovation. Implementing new technologies in shipping will rely on either the internal innovation of large corporate maritime companies or the valiant efforts of select startups that have chosen to tackle this problem area.
0.09 Gt
Trains
0.18 Gt
Scooters and bikes
Electric scooters and electric bikes are both mature categories of technologies. Current focus in this area is improving adoption and reducing emissions on a lifecycle emissions basis (e.g. avoiding waste, using electric vehicles for shared scooter pickup, etc.)
0.64 Gt
New air travel
New jet engines
Hydrogen planes
New engines
Full plane development
Airport-hosted refueling stations
Decarbonizing the airport
Electric planes
New electric propulsion
Full plane development
Most innovation in air travel is focused on creating electric-powered or hydrogen-powered planes. This requires the coordination of development between the plane manufacturers, the technology developers of the different components (engine or motor, storage, propulsion, etc.) and the regulatory bodies that govern testing before deployment.
15.8 Gt / 31%
Stuff
1 Gt
Separations (across industries)
1.9 Gt
Minerals
Mining decarbonization
Equipment upgrade/replacement
Low emissions hauling
Other battery metals (cobalt, nickel, REMs)
Nickel mining tech
New lithium extraction
Synthetic graphite
Sea-based mining
Sustainable minerals production can be divided into decarbonization of the mining sector, novel extraction processes, novel "feedstocks" (e.g. leachate, seawater), and artificial mineral production (e.g. synthetic graphite from carbon black). Much like oil and gas, mining faces global challenges to true decarbonization (much of the emissions is produced far from where emissions reduction efforts are strongest). The focus on resilient supply chains has spurred more minerals production efforts closer to the demand, which can help push through new technologies both through availability of capital and availability of new production sites for testing.
7 Gt
Fuels and Chemicals
Sustainable aviation fuels
0.9 Gt
Clean hydrogen
Plasma-based
Pyrolysis
Gasification
Electrolysis
Storage and logistics
Liquid carriers
Liquefaction
Solid state carriers
New compression
0.44 Gt
Clean ammonia
Clean hydrogen and ammonia face the complicated problem of decarbonizing their own supply chains (which typically makes product more expensive) while trying to disintermediate existing demand markets (which are highly cost-driven) and trying to grow into new demand markets (which are also cost-driven). Production costs are being subsidized by government incentives and some regulatory/market pressure is driving projects forward...but scaling low carbon hydrogen is still an uphill battle. Hydrogen's versatility remains a key feature of its appeal - as a potential carrier for renewable energy, feedstocks for new fuels, and energy-dense direct substitute for existing fuels, it has the ability to be just as important as the electron in the energy transition.
5.2 Gt
Oil & gas improvements / alternatives
Biofuels and electrofuels (except for others 1 level up)
Renewable diesel
Sustainable aviation fuel
Biogas / RNG
Butanol
Biodiesel
RSO/RSG
Measurement and verification
Nat gas processing + CCUS
Production Improvements
AI/ML
Pneumatic replacement
Leak detection and management
Storage replacement
Electrification
Many people are at odds when it comes to oil and gas' contribution to the energy transition and whether it makes sense to continue investment in fossil fuel production. There continues to be innovation driving down emissions in traditional energy production, resulting in new products like RSO/RSG that can offer a large volume drop-in substitute for our current hydrocarbon-based system. Biofuels of all varieties also continue to scale - namely RNG and renewable diesel recently due to their drop-in capabilties. Regardless of your stance on oil and gas' ultimate role in the next 20-30 years, current emissions from this branch are signficant and money placed to work reducing these emissions is a productive use of capital.
0.2 Gt
Clean methanol
Methanol + CCUS
Syngas to methanol
0.2 Gt
High value chemicals (ethylene, propylene, BTX aromatics)
0.06 Gt
Clean ethanol
Syngas to ethanol
Ethanol + CCUS
Chemical production relies on readily available and low cost building blocks. That being said, new chemical plants are difficult to build quickly and en masse, presenting a challenge to new processes interested in distintermediating the traditional production pathways in this category. Ethanol takes center stage in this category as both the most produced molecule from low carbon feedstocks like biomass or waste and the highest volume biofuel currently being used. It will be interesting to observe with all of the new pathways to produce ethanol and other chemicals whether production stays concentrated in current clusters or whether production becomes more distributed.
5.6 Gt?
Other industrial
7 Gt
Materials
2 Gt
Processing of packaging
0.3 Gt
Aluminum
0.3 Gt
Paper / Pulp
3.7 Gt
Clean steel
0.03 Gt
Carbon black
CO2 to carbon black via Bosch, pyrolysis, or other
0.68 Gt
Polymerization into plastics
2.3 Gt
Clean concrete / cement
Sustainable bricks
This category varies in between optimizing current processes to reduce emissions and replacing current processes with new processes altogether. For materials like aluminum and iron/steel, decarbonization mostly relies on replacing sources of process heat with cleaner substitutes. On the other hand, low carbon concrete/cement production can mean a variety of adjustments to the concrete production process. Even more differentiated is new carbon black production, which is produced from completely different feedstocks and processes than the traditional methods.
Recycling
Battery recycling
New consumer facing programs
Route optimization
Sorting robots
Item detection
Plastics recycling
Recycling is one of the categories here that has a close-linked but indirect relationship with climate change mitigation. While landfills produce some emissions,the real problem with waste is its pollution of the oceans and other natural features. The big recycling challenge is in economically monetizing what is essentially a waste product. Startups have to sell new investment into an inherently low cost, low margin industry and often times deal with conservative municipal customers.
17.3 Gt / 34%
Electricity and Heating/Cooling (except industrial)
13.3 Gt
Power gen and delivery
Resiliency
Batteries
Solid state
Flow
Iron air
New cathod/anode/electrolyte combinations
Batteries and non-battery energy storage have the difficult job of growing alongside an evolving primary generation landscape, which makes identifying the optimum set of KPIs in this area challenging. Cost is a huge factor in scalable storage for utility or commercial scale applications - and with supply chain issues placing pressure on certain materials, finding the right combination of low cost, readily available, and high performance components presents an even greater challenge.
Non-battery storage
Compressed air
Gravity
Molten salt
Pumped hydro
Hydrogen
Grid optimization
Fault and outage detection
Auto feeder switches
Microgrid
PMUs
Creating VPPs using a portfolio of DERs
Grid optimization can come in many forms- both behind the meter and front of meter, hardware and software, and targeting reducing outages in extreme weather scenarios or simply load sharing in day to day energy use. There's huge potential for AI and ML to make a difference in this arena, though the ability to iterate through technologies is limited by grid-accessible testing sites and regulatory processes.
Transmission and distribution
Dynamic line rating
Power flow controllers
Superconducting cables
Geothermal
EGS
Closed loop
Residential
Supercritical
New turbines
Oil well retrofits
Ocean energy
Salinity gradient
Wave energy
Ocean thermal energy conversion
Tidal energy
Geothermal and ocean energy both rely on specific geographical features to generate renewable energy. Both have a similar history of many R&D cycles and struggles with commercialization. Current climate tech fervor has breathed new life into these two old sectors. Those tailwinds, combined with several recent technological breakthroughs and some unprecendented multi-stakeholder intiatives, can certainly drive up adoption this cycle.
Thermal power gen
WTE
Oxycombustion
Nat Gas with CCUS
Coal with CCUS
Nuclear fusion
Biomass
Nuclear fission
SMRs
Thermal power generation is arguably the most contentious subsector in power generation. With the variety of technologies in this category, there's low visibility into which ones will ultimately displace the current thermal generation paradigm. Three large hurdles facing innovation in this space: availablity of project financing for new technologies, long and expensive R&D cycles, and slow regulatory responsiveness.
Solar
New lenses / geometries
Smart CSP
Floating solar
Perovskite
Wind
VAWT
DAWT
Blade recycling
Offshore wind platforms
New turbine design
Wind and solar innovation continues to benefit from the push for rapid deployment and the immense capital dollars that are being poured into development. The number of new farms means a wealth of opportunities to test emerging technologies. The modularity of wind and solar also helps increase the rate of innovation.
3.4 Gt
Building improvements
BIPV
Heat pumps
New HVAC
Insulation
Smart thermostats
Smart refrigeration
New coolants
Technologies in this cluster like heat pumps, HVAC improvements, smart thermostats, and new appliances are proven out and just require accelerated adoption across a distributed customer base. Financial and social innovations can make a big difference across these. There will be an interesting dichotomy between what technologies will be adopted into new building construction and what can be retrofitted.
N/A
Measuring / managing / trading carbon + other climate commodities
Adaptation technologies
Water desalination
Drought resilient crops
Gray water recycling
Fire resistant or fire proof materials
Improved disaster detection
Adaptation technologies is a broad category that can cover almost anything that helps us adapt to climate change. Right now this mostly includes improved prevention and responses to drought and wildfires. Eventually this will also evolve over time to include responses to other natural disasters as we start to see the certain consequences of climate change definitively manifest
Enterprise software
Carbon accounting
Net zero planning
Offsets management
Risk assessment
Emissions monitoring (from internal sources)
Carbon actions
Corporates will have greater responsibility to manage their carbon going forward. There are many software companies that have emerged over the last few years to help enterprises track their carbon footprint, plan out their net zero strategy, engage employees in carbon actions, and purchase/evaluate carbon offsets. As competition increases for corporate budgets, more startups will need to specialize. As it is now, with much of the corporate landscape still yet to be onboarded onto any platform, startups are racing to be first in the door in as many companies as possible.
Climate intelligence
ESG ratings
Emissions monitoring (from external sources)
Climate insurance
Climate intelligence has blown up in the last few years as companies and investors look to understanding climate risk and how to price and protect against that risk. The intelligence products in this category vary from asset-level emissions data platforms to company-level ESG ratings to complex multi-pronged climate modeling. As this data is still getting organized in an actionable way, entities, particularly financial institutions, are just starting to onboard products around this intelligence.
Carbon offset verification, monitoring, and creation
Project management platforms
Offset project crowdfunding
Offset APIs
Blockchain-based verification
Offsets marketplaces
Offsets databases
Linked closely with the CDR space, some tools and platforms have been developed around the carbon offsets economy to increase offsets liquidity, increase the quality of offsets being offered, and increase the transparency around offsets pricing. This category is very fragmented and operates in many different mini-marketplaces. It will be interesting to see how the major registries expand into some of these service areas.
Consumer-facing software
Sustainable investing tools
Offsets purchasing programs
Carbon footprint
Carbon actions
Many different apps and software platforms have been developed for the climate-conscious consumer and VC dollars have been eagerly put to work in this area. But despite all of this and general climate sentiment at an all-time high, actual adoption of these apps has been limited to a niche group of users. Most of the companies in this category face the challenge of keeping up user engagement. While consumers present a large potential market for a software-based model, consumer-facing climate software is still facing signifcant social hurdles in its quest to capture that market.
CDR
Ocean alkalinity enhancement
Enhanced weathering
Carbon mineralization
Soil carbon sequestration
Forestation
DAC
CDR covers a wide variety of project types, including those that act like industrial plants and those that act more like environmental remediation projects, which makes comparing projects across this category a challenge. Another challenge is that revenue for these projects will continue to be driven by carbon offsets (both voluntary and mandatory) and government incentives until the carbon utilization market matures. This dependency means that the economic value of these projects are highly levered to official and unofficial regulatory frameworks, which can be both complex and arbitrary.
‣ Root numbers are 2020, annual, and from Bill Gates' How to Avoid a Climate Disaster
‣ Emissions from child branches not necessarily additive to parent branches because of different data sources, methodologies, category definitions, and scopes (ideally all are scope 1 but unclear from sources)
‣ Power and building emissions: https://www.statista.com/statistics/276480/world-carbon-dioxide-emissions-by-sector/
‣ Separations emissions: https://arpa-e.energy.gov/technologies/projects/scalable-graphene-oxide-membranes-energy-efficient-chemical-separations
‣ Oil and gas emissions: https://www.iea.org/reports/world-energy-outlook-2018/oil-and-gas-innovation
‣ Methanol emissions (also includes use): https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2021/Jan/IRENA_Innovation_Renewable_Methanol_2021.pdf
‣ Methanol and ammonia emissions: https://www.iea.org/fuels-and-technologies/chemicals
‣ Methanol emissions again (final number is previous link + this link averaged) + ammonia emissions + fertilizer usage emissions + plastics emissions estimate (1.5 Gt - 0.44 - 0.18 - 0.2 = 0.68 Gt)
https://www.energy-transitions.org/wp-content/uploads/2020/08/ETC-sectoral-focus-Plastics_final.pdf
‣ Ethanol emissions (15,776 million gallons * 80 MJ/gal * 45 g CO2 / MJ = 56 megatons): https://onlinelibrary.wiley.com/doi/10.1002/bbb.2225
‣ Cement emissions: https://www.globalefficiencyintel.com/new-blog/2021/global-cement-industry-ghg-emissions
‣ Iron/Steel emissions:
https://www.carbonbrief.org/guest-post-these-553-steel-plants-are-responsible-for-9-of-global-co2-emissions#:~:text=The%20IEA%20reports%20that%20total,plants%20supplying%20electricity%20for%20steelmaking.
‣ Hydrogen emissions: https://www.iea.org/reports/hydrogen
‣ Carbon black emissions: https://chesterenergyandpolicy.com/2018/11/19/carbon-black-turns-green-how-g3c-is-offsetting-emissions-in-the-tire-industry/
‣ Mining emissions (GWP 100 number): https://www.mckinsey.com/business-functions/sustainability/our-insights/climate-risk-and-decarbonization-what-every-mining-ceo-needs-to-know
‣ Transport emissions: https://www.iea.org/reports/tracking-transport-2021
‣ Food emissions (assumes transport, packaging, and retail covered in other branches; livestock does not include crop for livestock or land use for livestock, which would move 2.2 Gt from land and 0.8 Gt from crop to new total of 7.2 Gt): https://ourworldindata.org/food-ghg-emissions
‣ Paper / pulp and other industrial (which includes machinery): https://ourworldindata.org/emissions-by-sector
‣ Packaging emissions, adjusted to include non-food packaging (assumes 50/50 food/non-food): https://ourworldindata.org/grapher/food-emissions-life-cycle
Note: emissions may not be additive across child branches due to differing source methodologies. Someday I'll reconcile the differences.