DRAFT Outline for ITIAC's Report

1. Executive summary (consider summary figure/illustration)
2. Introduction
    a. Committee purpose
    b. Justification for focus on industrial emissions
        i. Emissions, employment numbers, public health impacts (premature deaths, etc.)
        ii. context for industrial subsectors (e.g., how GHG emissions break down by industrial subsector)
    c. Evolving/emerging trends (keep this high level, with specifics in various sections)
        i. Electrification, availability of green electricity, new technologies such as high-temperature heat pumps and thermal batteries
3. Cross-cutting Technologies & Opportunities
    a. Energy efficiency
        i. Efficiency of specific machines, such as boilers, furnaces, etc.
        ii. Efficiency of integrated systems across a plant or cluster of nearby plants, such as compressed air systems, steam distribution systems, and heat integration (in-plant and district heating)
        iii. Maintenance best practices for energy efficiency (such as repair of steam leaks, condensate return, predictive or preventative maintenance practices- e.g. using sensors, etc.)
        iv. Digital techniques to optimize energy efficiency, such as process simulation (akin to digital twins), controls and optimization, machine learning, etc.
    b. Material Efficiency
        i. Product design for material efficiency and energy efficiency of manufacturing (i.e., designing products so that they can be manufactured with less energy, such as fewer process steps or lower temperatures).
        ii. Smart manufacturing
        iii. Digitalization of products (e.g., replacing material-intensive physical goods with material-free digital goods, like e-books or streaming video)
    c. Circular Economy

        i. Designing products to use less carbon-intensive supply chain inputs
        i. Product longevity – designing products for durability and repairability
        ii. Remanufacturing
        iii. Recycling
d. Electrification
    i. Electrification of process heating at all temperature ranges (using technologies such as high-temperature heat pumps, electric resistance, electromagnetic induction, electric arcs, infrared heating, etc.). Also, electricity can sometimes replace heating entirely (e.g., non-thermal use of electricity, such as electrolysis, UV curing of epoxies and coatings, or other electrochemistry).
    ii. Deeper dive into **industrial heat pumps**: heat source (waste heat, ambient, or geothermal), attainable output temperatures, efficiency, maximum power output / using multiple heat pumps in parallel, using heat pumps as a first stage when heating to even hotter temperatures, commercial readiness, cost
    iii. Deeper dive into **thermal energy storage**: how thermal batteries work, attainable temperatures, efficiency, how much of a discount they achieve on electricity costs versus buying electricity evenly in every hour (customer perspective – lower electricity prices)
e. Dynamic load management
    i. Grid support (how industrial facilities can co-optimize with electricity suppliers to add flexibility to the grid and avoid putting strain on the grid during hours of net peak electricity demand)
    ii. Demand response programs for industry
    iii. Creating an electricity rate plan that gives industry access to wholesale electricity prices that passes through real generation costs that vary over short (5-minute) timescales (note: this point also appears in the "Barriers" chapter)
    iv. How energy storage (including thermal) can support the electric grid (utility perspective – how industries can support the grid)
f. Use of low-GHG hydrogen by industrial firms
    i. Identify niche for hydrogen: ammonia and petrochemical feedstocks, hydrogen-direct reduced iron, refining

    ii. Recommend against hydrogen combustion for heat where direct electrification could provide the heat more efficiently
    iii. Hydrogen as a medium of energy storage (if/as relevant to industrial facilities, not utilities/grid)

g. Direct use of heat from renewable sources and bioenergy
    i. Direct use of heat from solar thermal or geothermal heat sources, inclusive of storage (not electricity generation)
    ii. Bioenergy (solid, liquid, gaseous) as feedstock or burned for energy

h. Self-generation
    i. How plants currently using combined heat and power (CHP) can transition to clean processes and still meet their heat and electricity needs. Steam is the main product and electricity is the byproduct, making it harder to transition to grid electricity.
    ii. Mention water needs and refer to Barriers section for the full discussion
    iii. Nuclear SMRs on industrial sites. E.g. DOW is building an SMR now. SMRs deliver both heat and power.
    iv. Geothermal, solar, wind, hydro electricity generation for use by the industrial facility.

i. Carbon capture, utilization, and storage (CCUS)
    i. Niche for CCS (process CO2 from cement calcination (especially once the heat is electrified), and from CO2-producing chemical reactions in refining and chemicals industries, and where CO2 is available with very high purity without need for separation)
    ii. Downsides of CCS (increased energy use and costs, upstream emissions from fossil fuel production and processing, potential for increased conventional pollutant emissions, need to develop pipelines and storage sites, high equipment and energy costs to do at large scale)
    iii. Better and worse uses or storage mechanisms of CO2 (how to store the CO2 for the long term, what products will not break down or be combusted and release the CO2). Maybe refer to OTT report on this topic.

j. Infrastructure needs for industry
    i. Electric power capacity (e.g., need for more zero- or low-carbon electric generation capacity, transmission and distribution lines, substations, etc.)
    ii. Hydrogen infrastructure

iii. Captured CO_2 compression, transport, and storage
iv. How to coordinate multiple users (multiple companies and/or district heat systems) to be joint customers of heat supply

k. Non-CO_2 GHG emissions (N_2O, CH_4, and F-gases)
   i. F-gases (refrigerants, propellants, semiconductor manufacturing, and SF_6 as electrical insulator, etc.) and how to address them (e.g., substituting safer-for-climate chemicals)
   ii. N_2O process emissions (e.g., nitric and adipic acid production, thermal or catalytic N_2O destruction)
   iii. Fugitive methane emissions (from oil and gas fields, coal mine methane, gas processing, transmission and distribution, and from industrial facilities such as fertilizer plants and dairy farms)

4. Industrial subsectors
   a. Criteria for selection of subsectors
   b. Selected subsectors are: (1) chemicals, (2) refining, (3) iron & steel, (4) non-metallic minerals - e.g., cement, glass, and brick, (5) food and beverage
   c. For each covered subsector:
      i. Brief overview of how the sector works today and its share of U.S. industrial GHG emissions, broken down by emissions type (e.g., combustion CO_2, byproduct CO_2, byproduct non-CO_2 greenhouse gases, purchased electricity)
      ii. Heat demands and temperature ranges for the processes used by this subsector
      iii. Fuels used as feedstocks (if any) by this subsector
      iv. Special considerations and challenges for this subsector (e.g., technological needs, how to deal with byproducts currently being burned as fuel, special supply chain needs, potential for downstream impacts on buyers, etc.)
   d. Other sectors not considered in this report, could tee up topics for future reports (could include lithium or other mining, controlled environment agriculture or CEA, supply chains for decarbonization technologies)

5. Barriers
   a. Electricity costs/market regulations – Sasha
      i. Need for electricity market reform to ensure critical industrial electrification technologies (e.g., thermal batteries) can access low value and clean power (during times of over generation /

periods of low demand) and pay cost-based transmission and capacity rates to compete with fossil fuels

   ii. Access to wholesale electricity pricing
   iii. Standardized electricity tariffs that recognize the value of highly flexible industrial loads and reflect real-time costs

b. Pilot to demonstration to deployment (and supply chain) - Neal
c. Technology gaps (where R&D can help) – Sue
d. How to address industries that burn their own byproducts as fuel (e.g., refineries burn refinery fuel gas and petcoke; pulp and paper and wood and wood products industries burn biogenic waste). The fuel is free today and would become a waste stream needing disposal or transformation into a sellable product if it could no longer be burned.
e. Water adequacy and energy-water nexus (needed for cooling, for CHP, feedstock for making hydrogen, etc.)
f. Infrastructure, permitting & policy support – Betsy, Neal
   i. How to get the required infrastructure built quickly, affordably, and efficiently.
   ii. Streamlining process for approving and building electricity transmission and distribution.
   iii. Infrastructure for other clean energy sources, such as green hydrogen or sustainable bioenergy
g. Financing and market demand barriers – Cathy
   i. *Note to coordinate with the similar points about financing and need for off-takers in the "Economic Competitiveness" section*
h. Policy drivers and/or private sector demand for long-term offtake of clean goods
   i. For a while, green government procurement programs can provide a reliable offtake market for cleanly-produced products, but eventually the private sector needs to be the main off-taker
i. Workforce needs; access to sufficient science, technology, engineering, and math (STEM) talent – Neal
j. Data access/quality and modeling – including standard metrics

6. Economic competitiveness
   a. Need for a carbon border adjustment mechanism (CBAM) or other GHG-based border fee to protect domestic industrial firms from competition from dirty producers abroad

        i. Need to track provenance and GHG intensity of imported products, perhaps coordinating with the European Union, which has the same data collection needs for their CBAM
    b. Addressing operating cost gap though policies such as tax credits or access to more favorable electricity rates
    c. Access to upfront financing for upgrading to clean industrial processes and equipment (grants, tax credits, low-cost loans)
    d. Ensuring a market for long-term offtake of clean goods
    e. Industrial technology exports – exporting and licensing American clean industrial technology to help clean up industries overseas while making the U.S. a global technology leader
    f. Alignment between U.S. and international standards to facilitate technology interoperability and policy compatibility. Examples:
        i. PFAS rules
        ii. Embedded carbon accounting (for CBAM)
        iii. Other standards harmonization
    g. Supply chain resilience (e.g. versus shipping disruptions, natural disasters, etc.)
7. Workforce and social considerations
    a. Workforce training – including manufacturing workers, and trades that support manufacturing like electricians, pipefitters, construction workers, welders, etc.
        i. How DOE can help turn this from a barrier to deployment to an opportunity
        ii. How to ensure community colleges and other training providers kept up with demand and train workers in the latest tools and processes
        iii. What changes to training programs or the types of training offered would help train workers (e.g., vocational training, etc.)?
    b. Workforce availability & demographics
        i. How to make careers in manufacturing and trades more attractive to young people
        ii. How to ease the pathway to careers in the skilled trades needed by industrial firms (for example, government-funded apprenticeship programs like the programs in Germany, etc.)
    c. Ensure sufficient access to workers with STEM and related skills:

        i. Engineering, computer, and technical skills – e.g., computer programming, data analytics, optimization, AI/ML
        ii. Ensure sufficient access to workers with security clearances to work on sensitive technology, such as programs to hire veterans, or ways to streamline security clearance process
    d. Manage any job disruptions and negative impacts of technology deployment on the workforce
    e. Community/stakeholder engagement when industries build new plants, retrofit or build additions to plants, or make other changes that impact the community (such as layoffs)
        i. DOE requiring info on this in Funding Opportunity Announcements
        ii. Community benefit plans
    f. How national labs help with workforce development
        i. Graduate programs with students at national labs. Develop/encourage mentorship programs. Use DOE funds to encourage lab personnel to do mentoring.
        ii. k-12 programs like robotics competitions
        iii. Labs develop training curricula
        iv. Lab-embedded entrepreneurship program (LEAP)
        v. Labs create software or hardware for use by technicians and workers
        vi. DOE can take an inventory of what each national lab does to help with workforce development and whether some labs could start new programs
    g. Occupational safety & health considerations
    h. Reducing pollutant impacts on frontline communities
8. DOE's Current Work Assessment and Gaps Analysis (NOTE: Builds on other chapters but brings in DOE context that is not necessarily present in other chapters, e.g. technology chapters talk about important technologies, this chapter talks about current DOE work in that space, what gaps need to be filled, prioritization for funding)
    a. Comprehensive overview of DOE’s existing activities and programs pertaining to accelerating a transition to clean and competitive U.S. industry - Jeff
    b. Comprehensive set of useful and actionable recommendations for DOE to help:

    i. Provide better data and computer modeling to assess clean industrial progress and needs (e.g., improving the coverage and frequency of Manufacturing Energy Consumption Survey, industrial sector coverage in the Annual Energy Outlook, etc.) – Jeff, Abigail
    ii. Optimize existing DOE programs and technology choices (what should each DOE office or program prioritize, which programs need more funding, etc.) – Comas, Abigail
        1. DOE analyzing redundancy vs. helpful overlap. And ensuring DOE offices talk with each other and coordinate.
    iii. Ways DOE can help seize opportunities or overcome barriers (e.g., identified in other ITIAC report chapters) – Cathy, Sasha
    iv. How DOE can serve as a coordinator (across agencies, labs, academia, industry, etc.) - Sridhar
    v. How DOE can use other helpful policy tools (such as administering tax credits, energy efficiency standards, demand-side support measures) – Jeff, Sasha
    vi. How DOE can advise other agencies (such as making recommendations to FERC on industrial electricity rates) - Sasha
        1. Influential role to play (with FERC, balancing authorities, states, Congress, etc) by evaluating and socializing the system benefits that come from dispatching key industrial electrification/decarbonization technologies (e.g., thermal storage) to utilize off-peak clean power and recommending market reforms to allow thermal storage to access wholesale markets
    vii. How DOE can best understand industrial needs and challenges and partner with industry – Sasha, Sridhar
9. Recommendations (NOTE: consolidate recommendations from earlier chapters so they are all shown conveniently in one place, not make new recommendations here)
10. Summary and Conclusions