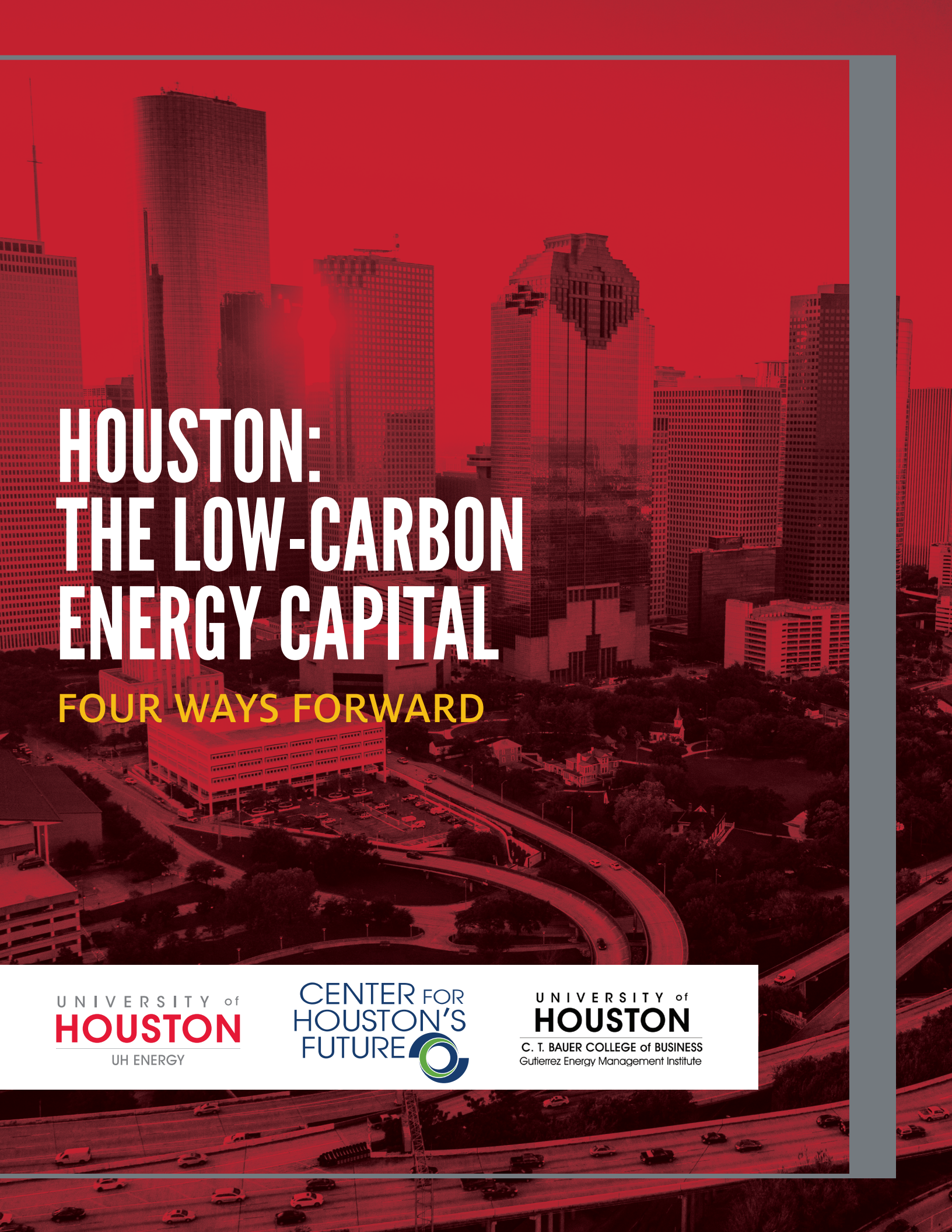

HOUSTON: THE LOW-CARBON ENERGY CAPITAL

FOUR WAYS FORWARD

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Houston Low-Carbon Energy Future: Four Ways Forward

The world is moving to an energy future that involves reducing the environmental impact of energy use while ensuring modern energy access for a growing global population. This will require reducing the emissions of existing hydrocarbon fuels, developing renewable energy sources and deploying new energy use and energy efficiency technologies.

Greater Houston is the global hub for energy, and the city of Houston has set a goal of becoming carbon-neutral by 2050. Analysis done by a team from the University of Houston's Bauer College of Business – Gutierrez Energy Management Institute, Center for Houston's Future (CHF) and UH Energy outlines four areas in which the Houston region can lead the global energy transition while reducing the region's carbon emissions, which are estimated at around 50 million metric tons per year for the industrial sector alone. CHF staff, UH faculty and students and an outside consulting firm conducted a six-month study of Houston's potential to lead the energy transition.

This work is the first to quantify the scope, size and challenge required to decarbonize Houston's industrial and power sector and to envision what new industries might emerge and infrastructure might be developed from those efforts. It does not address the transportation sector, the third major source of emissions in the region.

The assessment details opportunities and challenges as the region seeks to lead in four areas: carbon capture, utilization and storage; hydrogen; decarbonizing the electricity grid; and the circular economy/plastics recycling. Among the key findings:

- Carbon management technologies could remove more than 12 million tons of carbon per year by 2030, focused on industrial sites in the greater Houston area. CCUS also will be a crucial enabler of other emissions-reduction strategies, including hydrogen, petrochemicals and renewables integration.
- Houston, already anchoring the world's premier hydrogen system in terms of production and pipeline and storage infrastructure, has the potential to globalize its leadership by exporting clean hydrogen to meet growing demand stimulated by decarbonization initiatives globally.
- Texas can reduce the carbon intensity of the grid by 78% by 2050, even without energy storage, with 55% wind, 19% solar and 6% nuclear generation. With the addition of lithium ion battery storage and compressed air energy storage, the grid could be almost 90% carbon-free.
- Chemical and heat-based methods of breaking down plastics for recycling could provide an alternate route to produce feedstock for chemical and petrochemical facilities across the Houston region. The effort could remove 10 million metric tons of CO_2 by 2030, while supporting 100 advanced recycling facilities by 2030, each capable of processing 25,000 tons per year and supporting a total of 15,000 jobs and half a billion dollars in payroll. By 2050, those impacts could grow by at least a factor of three.

Houston already has a highly skilled energy workforce, along with the academic institutions that can prepare the workers of tomorrow. The region also has the initial infrastructure in place, the technology innovation and policy innovation pipeline and the global partnerships to do this at scale and with urgency. The assessment identifies what's feasible and lays out a pathway to decarbonize the region and maintain Houston's role as the world's energy leader during the energy transition.

Carbon Capture, Utilization and Storage – Ready for Commercialization

The International Energy Agency and Intergovernmental Panel on Climate Change have declared the broad deployment of carbon capture, utilization and storage (CCUS) essential if we are to meet global climate targets. It is also essential if Houston is to remain the energy capital of the world. The ability to capture CO_2 emissions from oil and gas operations, the petrochemical sector and the electric power sector – and to have those emissions safely and permanently stored or converted to a useful product – is both an opportunity and a challenge.

Expanded CCUS also will enable many of the other emissions reduction strategies, including hydrogen, decarbonized electric power and the circular plastics economy. If Houston is to achieve its goal of net zero by 2050, the region clearly must move on from business as usual in order to continue supplying reliable and affordable energy to the world while leading decarbonization efforts.

Houston's long history with the oil and gas industries make it uniquely suited to lead in CCUS. We have geologic capacity for carbon storage and enhanced oil recovery efforts that is unmatched anywhere else in the world. We have the necessary pipeline infrastructure to jump start our beginning and an industrial framework to expand. Marketplace players with a desire to de-carbonize along with their engagement with academia to develop the necessary workforce of the future are equally important.

Getting there will require substantial investment as well as smart policy and regulation, including enhanced incentives such as federal tax credits under Section 45Q and marketplace incentives at both the state and federal level.

Financial return on the investment will likely be low for several decades and will require commitment from industry players. The right policies to accelerate and expand CCUS in Texas can lead to the long-term sustainability of jobs, heighten the city's investment profile and support economic growth, and lead to new low-carbon products for the marketplace.

Houston's advantages

A recent National Petroleum Council study on the "at-scale deployment of CCUS" made clear that Houston and Texas offer world-leading advantages because of our unique cluster of industries, geology and business opportunities for not only disposal but commercialization of CO_2 as a useful product.

Despite that, although basic CCUS technologies have been around for decades, relatively few commercial projects have been established. There is significant infrastructure available in the nine-county Houston region, key to accelerating deployment over the next decade as we activate a full-scale move to implementation. Assets that can activated over the next decade to jumpstart Phase 1 include:

- The Denbury Greencore Pipeline, with 13 million tons/year in available capacity to transport CO_2.
- Geologic storage accessible to the Gulf coast and capable of receiving 1.4 billion tons of CO_2 for enhanced oil recovery and an additional 1.5 trillion tons into saline formations.
- An initial focus on strategic CO_2 emissions in the Houston region would remove 5.7 million tons/year from hydrogen steam methane reforming operations and an additional 7 million tons/year from natural gas power generating facilities.

Baseline assumptions assume $40/barrel oil and a 45Q federal tax credit of $35/ton for CO_2 utilized and permanently and safely stored in the process of Enhanced Oil Recovery (EOR) utilization. Full use of saline storage capability is modeled at the current tax credit of $50/ton for storage only. We approached this as a CCUS business and not an exercise in government funding of institutional research projects.

How do we get there?

Existing infrastructure, coupled with adequate financial incentives, will allow the region to demonstrate the large-scale practicality of CCUS, along with its ability to remove more than 12 million tons of carbon per year during Phase 1.

Phase 2 and Phase 3 will be more difficult but achievable. In **Phase 2**, between 2030 and 2040, this will require:

- Expanding CO_2 capture to include an additional 6.4 million tons/year from natural gas-fired power plants and 13.5 million tons/year from refining, petrochemicals and other industrial processes.
- Expanding a pipeline to east and central Texas and into the DFW basin to provide as much as 30 million tons/year of capacity to reach additional geologic storage targets. Cost of a 250-mile pipeline expansion is estimated at $500 million.
- That would provide an additional 3.6 billion tons of available storage for enhanced oil recovery and 500 billion tons of saline storage. The reach into this region will also be augmented by the exploration and discovery of offshore CO_2 geologic storage.

Phase 3 will take the region to 2050 and net zero targets by:

- Expanding capture to include 11.4 million tons/year from industrial furnaces and 7.8 million from refinery catalytic cracker facilities and realizing the aspiration of fully capturing the region's CO_2 emissions. But that is not the entire story.
- A 500-mile CO_2 pipeline from Houston to the Permian, capable of transporting 20 million tons/year. Cost is estimated at $1 billion to access a globally unmatched geologic zone for storage of CO_2.
- This would provide an additional 4.8 billion tons of storage for enhanced oil recovery and 1 trillion tons of storage in saline formations; it would also enable expansion of the Permian EOR potential as well as the geological assets in Texas being used by industry from throughout the United States.

Substantial capital will be required to construct both facilities and pipelines, but the payoff will be felt far beyond the nine-county region, benefitting all of Texas in terms of jobs and a leadership position in the coming sustainable energy economy.

Geologic storage capacity for CO_2 here is expected to attract interest from throughout the continental United States, which would allow for an impact on emissions from industrial sources beyond the Gulf coast. Globally there will be demand for the technology and knowhow created here, as well as for the low-carbon products that will be competitive in the future marketplace.

CCUS is not only a requirement, it is an enabler for our region to continue to grow and grow sustainably.

Pathway to a Low Carbon Electricity Grid

Texas has made significant progress in reducing carbon intensity of the electric grid over the last 10 years. Texas leads the nation in wind installations, with over 27,000 megawatts (MW) installed at the end of 2019, and another 4,000 MW expected to be in service by year-end 2020.

In less than a decade, the fraction of energy supplied by renewables has more than doubled. The growth in renewables and a dramatic reduction in coal generation (from 40% of supply to 20%) has resulted in CO_2 intensity declining by 30%, from 1,206 pounds per megawatt hour to 850 pounds per megawatt hour (MWh) since 2010. Texas is well positioned for renewable power expansion, and Houston can be a major leader in this effort. Many of the required components are already in place.

The state has top-tier wind and solar resources, an independent power grid, one of the largest unregulated retail power markets in the world, and suitable salt dome geography to support energy storage along the Gulf Coast and in East Texas and West Texas. The Electric Reliability Council of Texas, or ERCOT, operates the electric grid and manages the deregulated market for 75% of the state.

However, the pathway to a net zero grid faces three key challenges. First is the mismatch between renewable production and load profiles. Second is the variability of renewable production (both throughout the day and seasonal) vs. traditional baseload generation. The third is an existing base of "must-run" CO_2 emitting resources (minimum output from online coal units, cogeneration units, and units online to provide ancillary services).

The Texas grid can achieve nearly 80% zero carbon by 2050 without energy storage. This would include:

- 55% wind
- 19% solar
- 6% nuclear generation

In this scenario, CO_2 intensity declines 78%, from 850 pounds per MWh in 2019 to 191 pounds per MWh in 2050. However, with a lack of energy storage, about 22% of potential wind and solar generation would be curtailed.

With the inclusion of lithium ion battery storage and compressed air energy storage to hold excess renewable generation, the grid can achieve an almost 90% carbon-free electricity supply. Unfortunately, the financial return for such technologies is diminished as storage capacity grows, making a 100% carbon-free grid unlikely with only these storage technologies.

The grid could reach the zero-carbon threshold by using hydrogen to balance supply and demand over seasonal periods. Green hydrogen could be produced through the electrolysis process, splitting water into the component oxygen and hydrogen by using an electric current generated by renewable resources. The resulting hydrogen can then be stored indefinitely for later use. Green hydrogen production could leverage existing natural gas storage, transportation and power generation infrastructure to reduce its cost.

The greater Houston community can cement a leadership role in grid de-carbonization. Texas is the largest energy consuming state, the largest industrial energy consumer, and it has the largest electricity market in the US. Many of the global-scale energy players with large Houston presences are increasing low-carbon investments to address climate-related risks to their businesses.

We also have a concentration of major renewable energy developers and owners, as well as many large retail power companies. Finally, we have a highly skilled and diverse energy workforce that can be re-deployed to accelerate the transition.

The Houston Region as a Global Hydrogen Hub

Hydrogen is generating increased attention for its significant potential as an anchor in a low-carbon future, amid growing momentum for decarbonization around the world.

Since the start of 2020, regions and countries have detailed critical roles for hydrogen in meeting decarbonization goals, including the European Commission, Germany, The Netherlands, Norway, Portugal, Spain and France. Preeminent energy companies such as Shell, BP and Repsol have announced hydrogen plans to help meet their low-carbon goals.

As such, the global hydrogen market is expected to grow by some $800 billion by 2050. Total market projections, including hydrogen gas and related technologies such as electrolysis and fuel cell equipment, are estimated by the Hydrogen Council as $2.5 trillion in 2050.

Greater Houston already anchors the world's leading hydrogen system, which produces approximately one-third of the country's total hydrogen gas annually. It's built on an expansive network of more than 900 miles of hydrogen pipelines – more than half of the country's hydrogen pipelines and one-third of hydrogen pipelines globally – and geologically unique, substantial salt cavern storage capacity.

The system primarily serves Gulf Coast refining and petrochemical operations. By leveraging this system, the area has the potential to bring substantial volumes of hydrogen to new markets rapidly and at scale and doing so in ways that would curb regional emissions.

Our research identified additional promising early targets including regional trucking – cutting emissions by replacing diesel with hydrogen - and exporting to markets that offer incentives to use hydrogen such as California.

To help catalyze local efforts, we propose demonstration pilots in the next few years that would focus on our existing hydrogen system, which primarily uses steam methane reformation technology, or SMR, to separate hydrogen from methane. That results in grey hydrogen.

Applying carbon capture, utilization and storage (CCUS) technology to the SMR process pulls out carbon emissions, creating what is referred to as blue hydrogen, which would reduce carbon emissions by 15 million tons per year if installed across the existing grey system. Over time, a blue system anchored in Greater Houston could be a major hydrogen exporter as several markets across the world are projected to not have enough hydrogen to meet their decarbonization goals.

The Greater Houston area is also primed to create no-carbon green hydrogen, produced by splitting a water molecule via electrolysis, which is a power-intensive process. Texas is the No. 1 state in installed, low-priced wind power and has a growing solar market that could help expand low price hours and support more electrolysis.

As well, using hydrogen as a means of energy storage offers the potential to add more renewables onto the Texas power grid by balancing renewable power intermittency.

We detail four key initiatives to kickstart these blue and green hydrogen market opportunities:

- Launching a pilot for heavy trucking operations.
- Adding CCUS to the SMR system to produce blue H_2.
- Piloting seasonal storage that uses hydrogen caverns and low-price power.
- Advancing other long-duration hydrogen storage opportunities paired with renewables.

These initiatives could cost between $600 million and $900 million by 2030 and require targeted policy and public funding to allow for new infrastructure, equipment incentives and permitting.

Building on these activation efforts – as part of a three phased approach to activate, expand, and rollout the H_2 economy – Houston could capture further value from both new regional and export markets by expanding the CCUS system to add additional existing Gulf Coast SMRs – as well as building new grey hydrogen capacity, potentially using newer technology such as autothermal reforming (ATR).

This would further leverage the Houston region's extensive scale and cost advantages across the chain: proximity to reservoirs for carbon use in enhanced oil applications or for carbon sequestration, access to low cost methane, abundant hydrogen storage capacity, and extensive port commodity export capabilities.

Houston has the potential to globalize its leadership in hydrogen, becoming the leading global hydrogen production and trading hub as blue and green technologies advance and costs decline – presuming that appropriate policy frameworks are created to incentivize nascent carbon and hydrogen markets.

The Circular Plastic Economy – How Can Houston Lead?

Plastic use and production have grown globally at a remarkable rate over the last five decades. Unfortunately, the resulting plastic pollution has also become ubiquitous, recognized as a global problem. The Houston region is uniquely suited to lead and implement solutions.

About 5% of plastics used worldwide become unmanaged waste, tossed in landfills or otherwise disposed of without a way to either divert the waste stream or find new life for the material. About half of that volume enters the world's oceans. In the U.S., plastic waste is well managed, and very little gets into the marine environment. Nevertheless, recycling rates for plastics are abysmally low in the United States. One example: only about 25% to 30% of packaging and single-use plastics from food services are recycled. Most of our plastic waste is incinerated or sent to a landfill.

The amount of plastic used in the United States alone is staggering:

- 37 million tons of plastics were used in 2019, up from 0.4 million tons in 1960.
- 16 million tons of that is single-use packaging and food services.
- About 85% of single-use plastics are comprised of polyethylene terephthalate, known as PET, the plastic used for soft drink bottles; high density polyethylene, HDPE, used in milk jugs; low density polyethylene, LDPE, used for plastic films and wrapping; and polypropylene (PP). PP is used in packaging, textiles and industrial applications.

All of that plastic carries a heavy toll in emissions. In 2015, the CO_2 equivalent emissions for plastics manufactured in the Houston area over their lifespan was about 30 million metric tons.

The nine-county Houston Metropolitan Statistical Area is a singular location for plastics manufacturing, with significant production infrastructure and activity. For instance, more than 80% of the polyvinyl chloride (PVC) manufactured in the United States is produced in Texas and Louisiana. The fact that we already manufacture plastics here, along with the region's low energy prices and the increasing availability of price-competitive renewable electricity, place Houston in a unique position to lead the circular plastics economy.

The benefits would go beyond reducing plastics pollution, potentially supporting 15,000 new jobs and a half a billion dollars in annual payroll by 2030. The actions could reduce greenhouse gas emissions impacts by 10 million metric tons of CO_2 per year.

The circular plastics economy is a way to describe a system in which plastic materials never become waste, a permanent solution to plastics pollution. The transition will require a fundamentally different approach to the way we design, use and reuse plastics.

The potential upside is huge, illustrated by an estimate of the amount of plastic waste generated historically and into the future. To quantify the effort, UH Energy has developed a model to estimate the amount of plastic waste generated in a given year, based on the amount of a plastic consumed in end-use applications and the lifespan of the plastic in that end use.

Broadly, the circular plastic economy is made up of three distinct elements that must be simultaneously developed:

- Effective recovery of end-of-life plastics
- Reuse of recovered plastic through recycling
- Design or redesign of plastic products to enable recycling

There isn't a single answer. Plastics recovery, reclamation and recycling, from cleaning and sorting to reuse, mechanical and advanced recycling processes, vary dramatically by sector – industrial, commercial and residential – and by type, from durable to non-durable and single-use materials. Connecting those value chains, especially the commercial and industrial sectors, into the circular plastic economy remains a unique opportunity for Houston.

Addressing single-use plastics is of the most immediate concern. And addressing the commercial and industrial value chains provides an immediate use case for improved tracking, recovery and reuse. In the longer term, broadening the sorting and separation beyond rigid PET and HDPE will provide a unique business opportunity that could be leveraged through appropriate policy or incentives.

Houston would have a distinct advantage in the area of Advanced Recycling Routes, or what is sometimes called chemical recycling – a group of technologies that can convert plastic waste back into the original polymers that can be reused for new plastics, fuels and other products. The use of solvolysis and pyrolysis – chemical and heat-based methods of breaking down plastics – could provide an alternate route to producing the feedstock for the extensive chemical and petrochemical facilities in the Houston region and extending across the Gulf coast region of Texas and Louisiana.

Based on current production capacity, and the amount of different types of plastic waste generated, this ecosystem could support about 100 such advanced recycling facilities in the Houston area by 2030, each at a cost of $35 million and capable of processing 25,000 tons per year, and in total supporting 15,000 jobs and half a billion dollars in annual payroll. It also would save 5,000 jobs and reduce greenhouse gas emissions impacts by 10 million metric tons of CO_2 per year.

By 2050, these facilities and economic impacts are likely to grow by at least a factor of three –300 advanced recycling facilities, each processing 25,000 tons of plastic annually, and supporting 45,000 jobs – as a result of improved collection rates, a growing use of durable plastics in construction for buildings and infrastructure, and population growth.

About the Organizations

UH ENERGY

UH Energy is an umbrella for efforts across the University of Houston to position the university as a strategic partner to the energy industry by producing trained workforce, strategic and technical leadership, research and development for needed innovations and new technologies.

That's why UH is the Energy University.

GUTIERREZ ENERGY MANAGEMENT INSTITUTE

The Gutierrez Energy Management Institute (GEMI) is responsible for the energy education program in the Bauer College of Business at the University of Houston. Our scope includes energy-focused degree and certificate programs for undergraduate and graduate students and energy professionals. We develop student employment, internship and consulting project opportunities in the energy industry. We also conduct research and host events to bring industry executives, faculty and students together to address industry issues.

CENTER FOR HOUSTON'S FUTURE

CHF brings business, government and community stakeholders together to engage in fact-based strategic planning and collaboration on issues of great importance to the region. It engages in economic research and strategic planning, holds community events and develops leaders. The Center is an independent affiliate of the Greater Houston Partnership. Its leadership program has graduated more than 1,100 business and civic leaders.

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