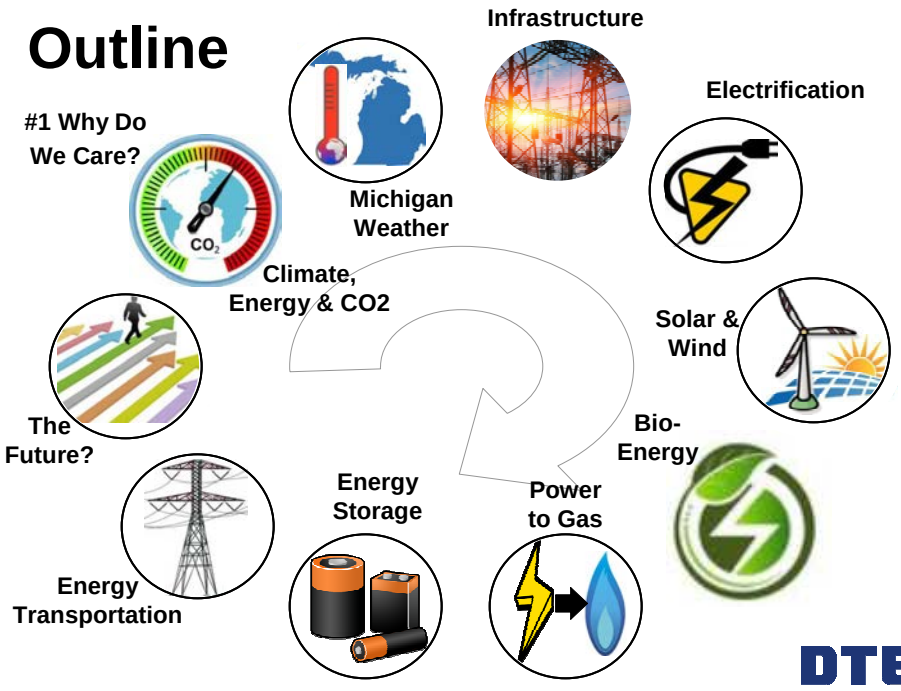
Data Driven Low Carbon Energy for Sustainability

Low Carbon Solutions for Michigan in 2019 and Beyond

James Leidel
DTE Energy, Gas Major Accounts
October 2019

Outline



Why Should We Care ?

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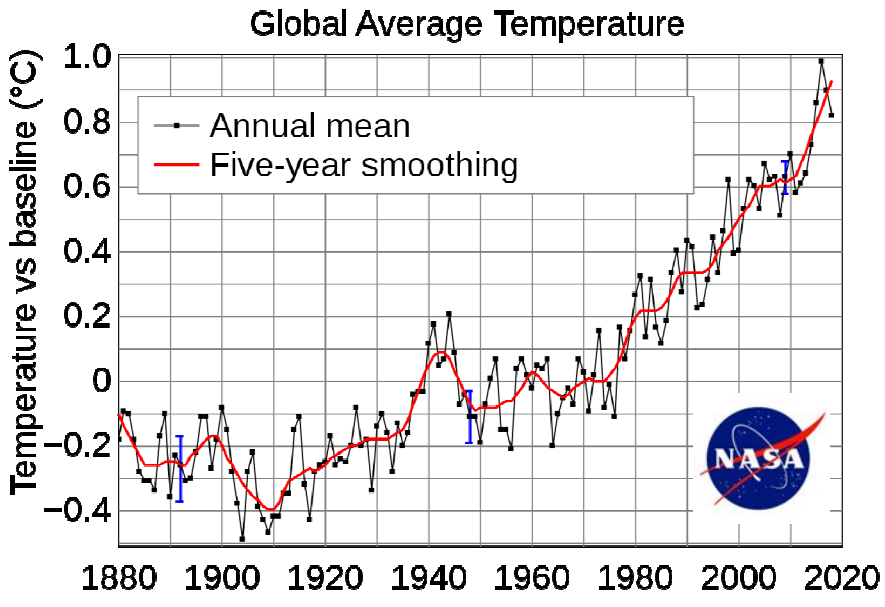

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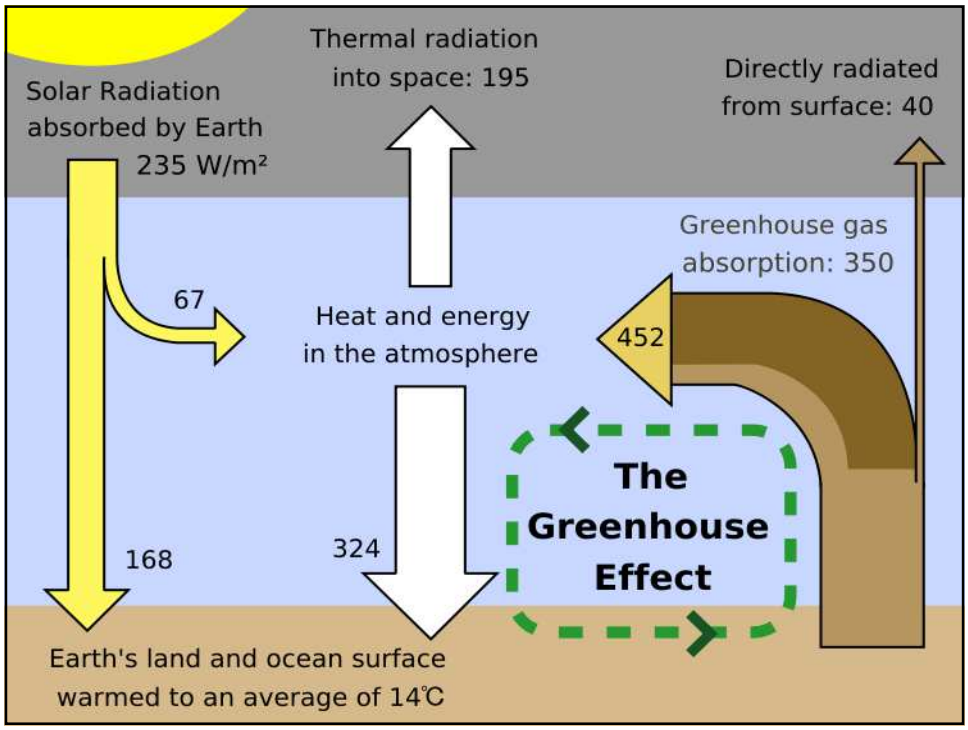
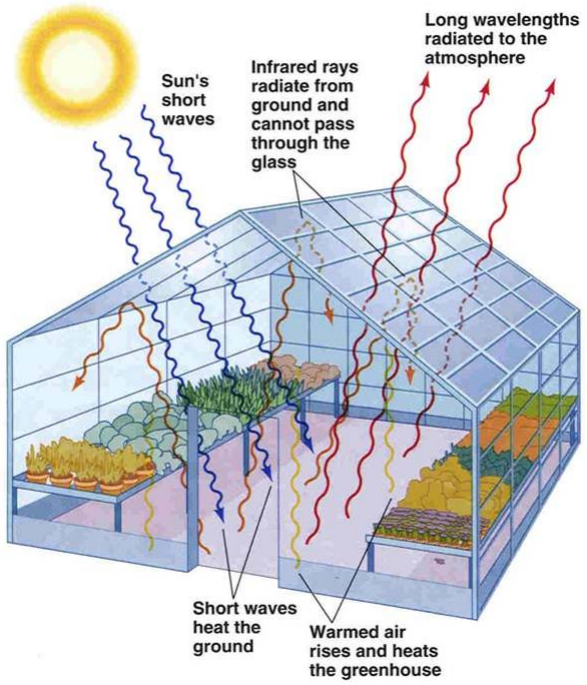
Source: https://data.giss.nasa.gov/gistemp/

If you ‘cherry pick’ your data, you can obscure the actual trends (global cooling?)

https://climate.nasa.gov/blog/2893/nope-earth-isnt-cooling/





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Michigan's Weather is Changing

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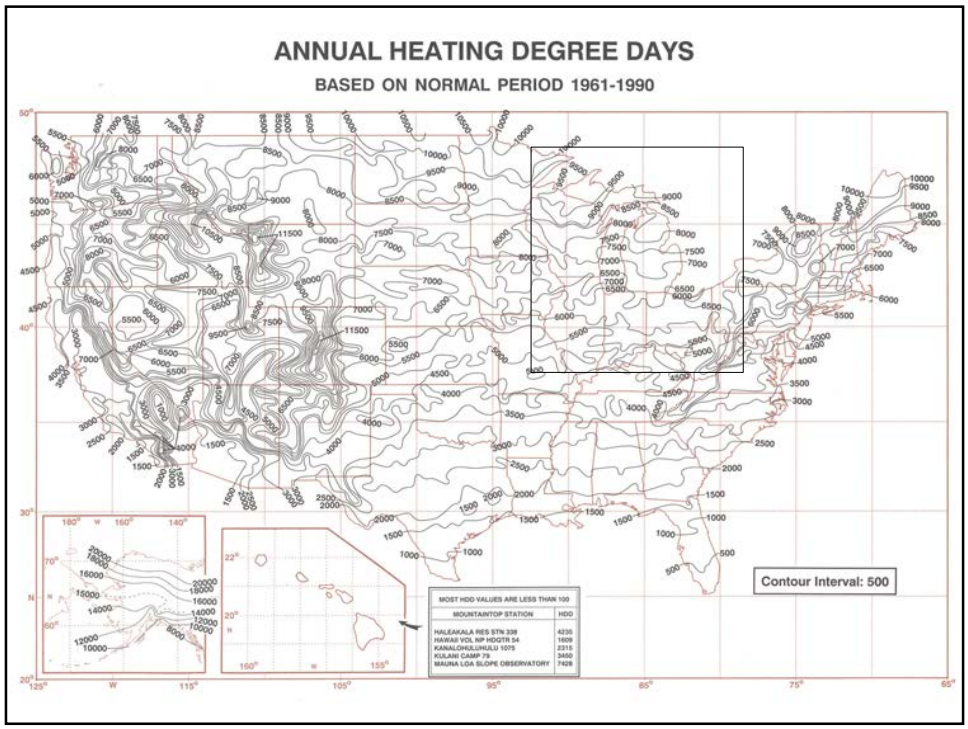
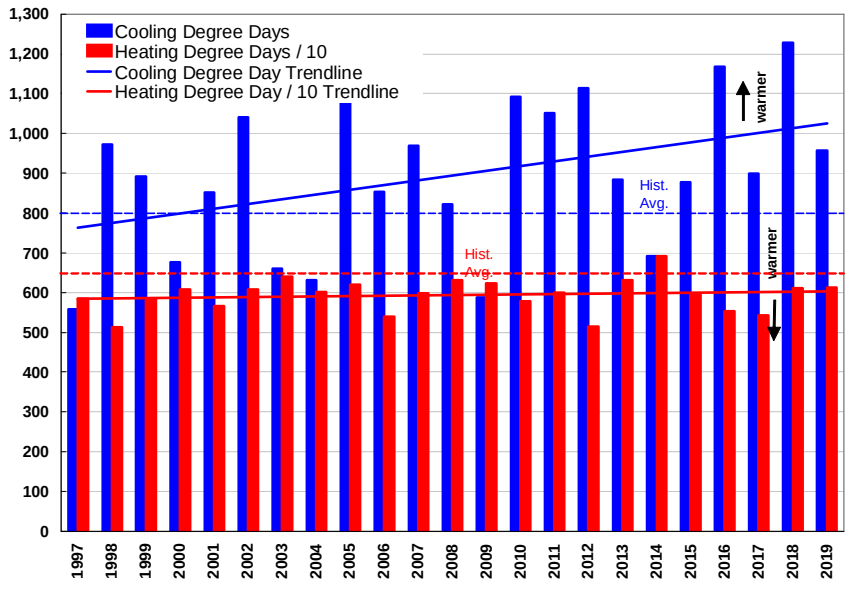


Michigan Summers are Warming, Winters Static

Detroit, MI Historical Degree Days



Michigan Summers are Warming, Winters Static

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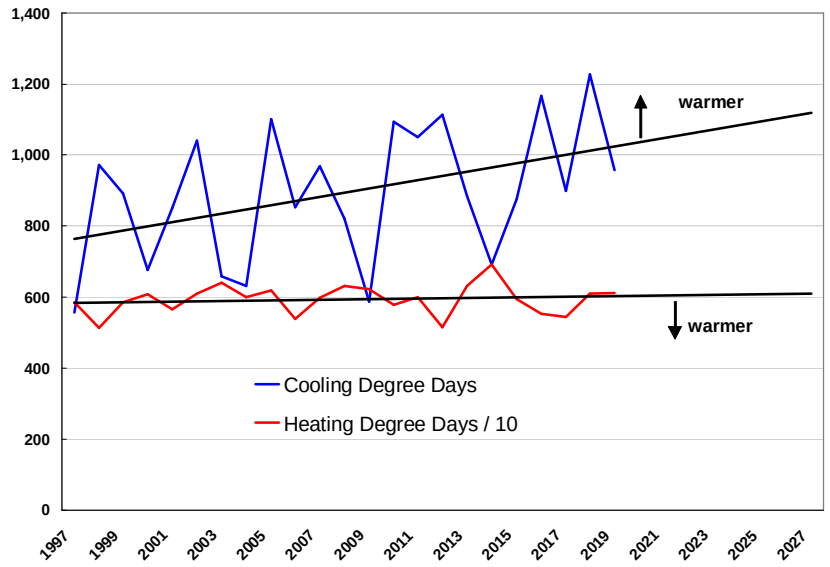
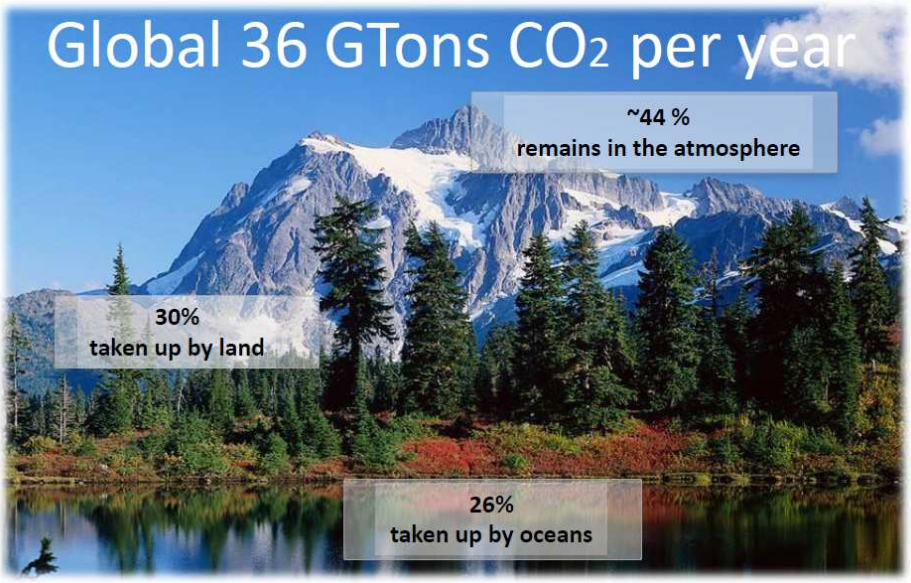


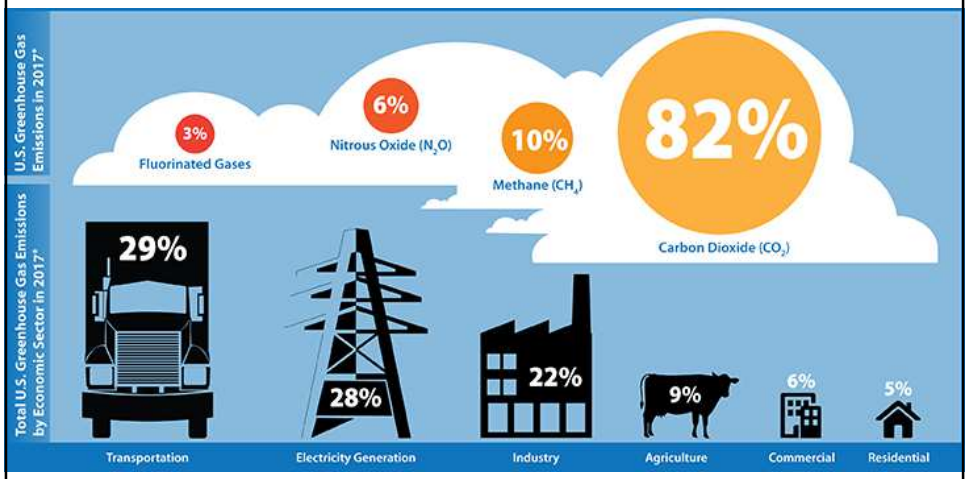
~44% of CO2 Emissions Remain in the Atmosphere



https://www.co2.earth/global-co2-emissions

CO2 is the largest Greenhouse Gas

2017, Greenhouse Gas Inventory Explorer

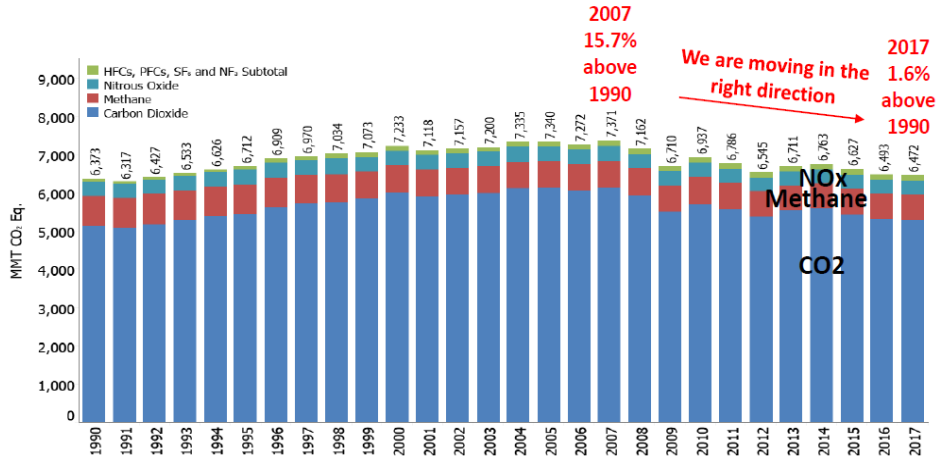


https://cfpub.epa.gov/ghgdata/inventoryexplorer/

EPA United States Environmental Protection Agency

The past decade has seen a drop in CO2

U.S. Greenhouse Gas Emissions: 1990-2017



Source: U.S. Inventory of Greenhouse Gas Emissions and Sinks: 1990-2017, https://www.epa.gov/ghgemissions/draft-inventory-us-greenhouse-gas-emissions-and-sinks-1990-2017

Sometimes Change Happens Slow

Powering toward a net zero carbon future

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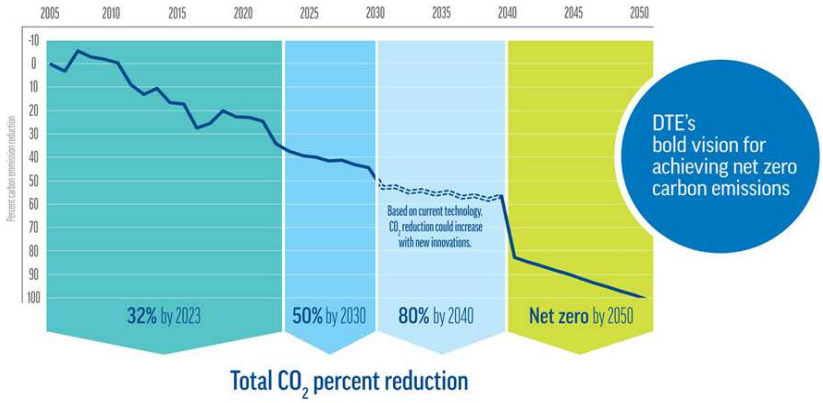
Our goals and progress to date



And….

Sometimes Change Can Happens Fast

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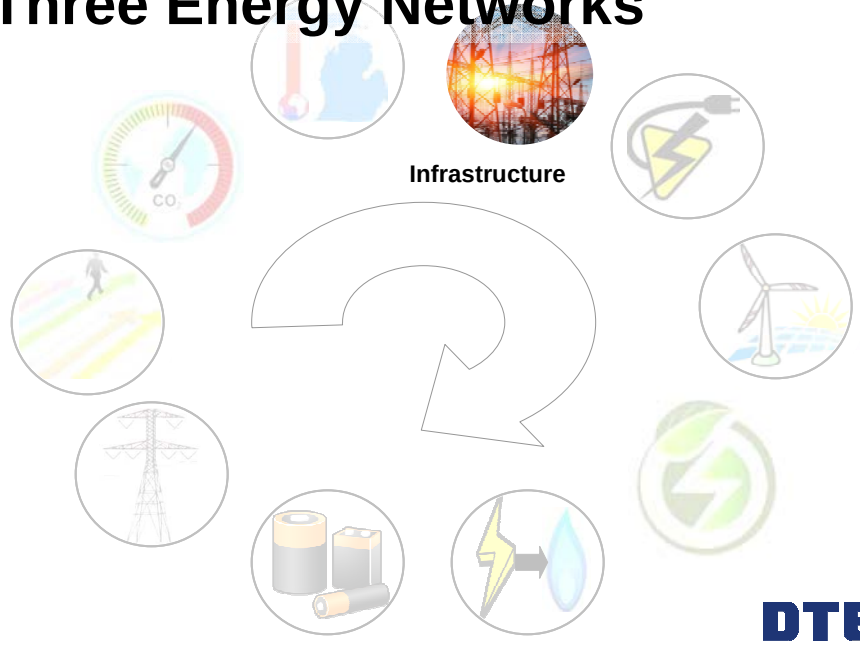
Three Energy Networks



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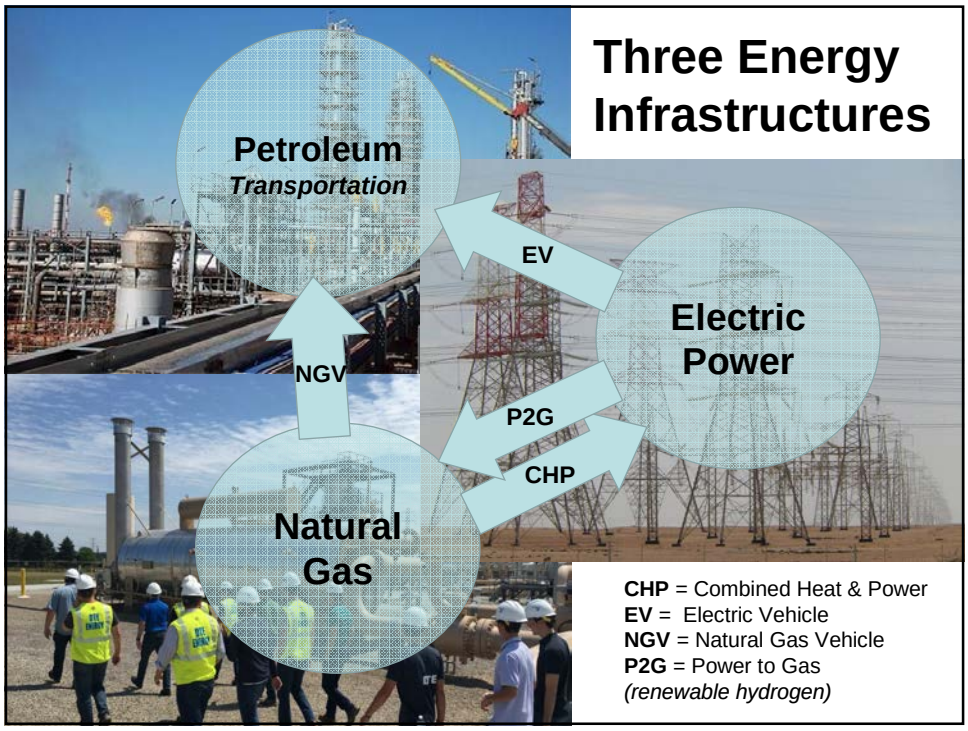
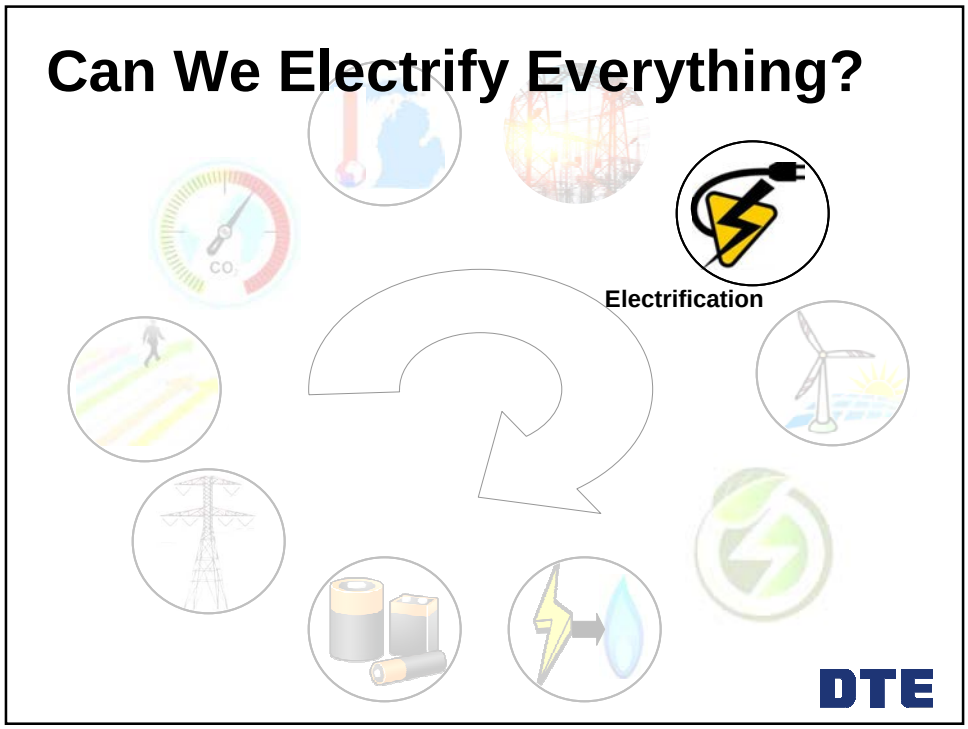

Three Energy Infrastructures
Petroleum
Transportation
EV
Electric Power
NGV
P2G
CHP
Natural Gas
CHP = Combined Heat & Power
EV = Electric Vehicle
NGV = Natural Gas Vehicle
P2G = Power to Gas
(renewable hydrogen)


Can We Electrify Everything?
Electrification
DTE

It would be very difficult and costly to fully electrify Michigan fossil fuel usage

	GWh
Electric power, fossil fuel usage	199,648
Est. generation to fully electrify	457,614
	GW
Approx. electric summer peak	20
Approx. January natural gas peak	96

(See handout for calculations)

Residential heating:

natural gas solutions have significantly lower carbon footprints (in Michigan)

Annual CO2 Production		Year 2030	Year 2030	Year 2030
	Grid Electric	Grid Electric	TOTAL	(+/-) from HP
	tons CO2	tons CO2	tons CO2	%
Electric heat pump	42,504	21,252	21,252	
Natural gas furnace std eff.	21,500	10,750	25,018	17.7%
Natural gas furnace high eff.	21,500	10,750	23,066	8.5%
Natural gas heat pump	21,500	10,750	20,500	-3.5%
micro CHP + high eff furnace	2,150	1,075	18,433	-13.3%

The 2030 electric grid CO2 goal is to be reduced by 50%

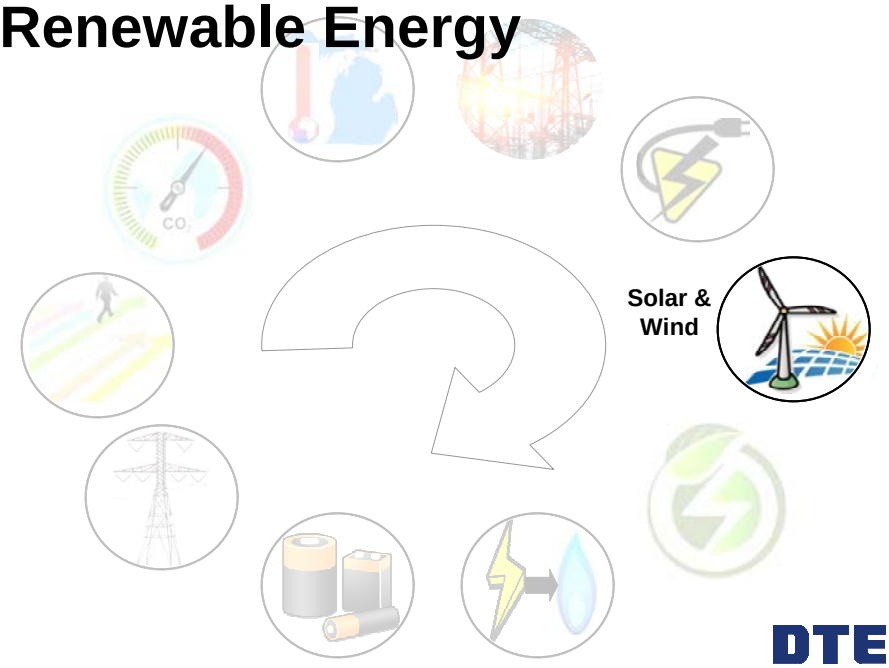
(See handout for calculations)

1 MW Power Generation Example:
Natural gas CHP provides lowest investment per tone of CO2 reduced

Technology	Installed Cost	CapEx Required
	$M per MW	$ per (ton CO2/yr)
Solar	$1.50	$1,098
Wind	$1.80	$546
Battery Storage	$2.43	n/a
Solar + Battery	$3.93	$2,877
Wind + Battery	$4.23	$1,283
CHP	$2.00	$497

(See handout for calculations)

Renewable Energy



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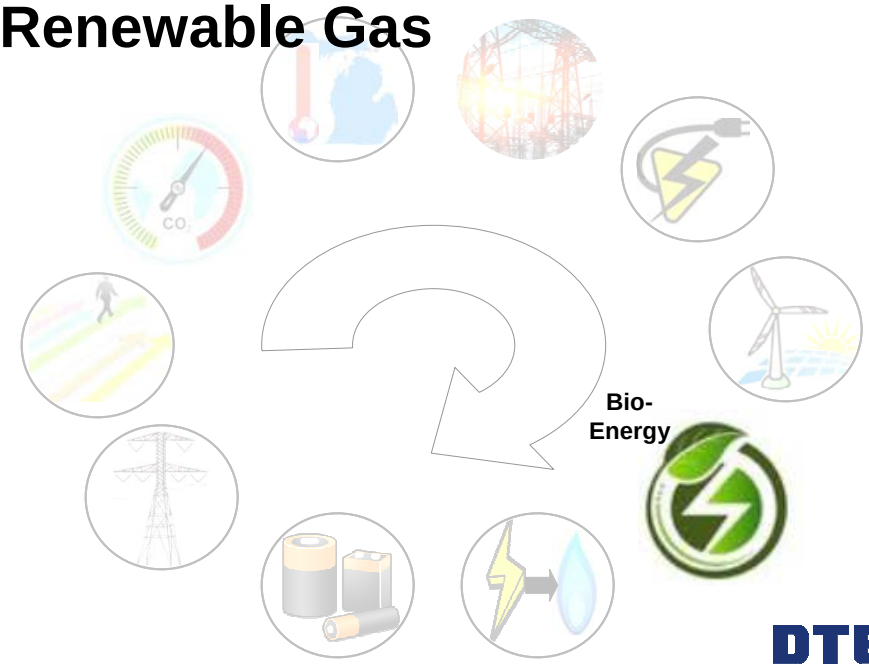
Solar and Wind energy are the cheapest form of new energy.

- Both are intermittent
- Both require base-load balancing generation and/or energy storage
- Wind & solar contracts < $0.04/kWh

Renewable Gas



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Terminology: RNG is raw biogas cleaned to pipeline quality

- **Bio-Gas:** high methane gas from anaerobic digesters or thermal gasification. Contains some H20, CO2 and potentially N2, O2, siloxanes, etc.
- **RNG:** renewable natural gas, is “upgraded” biogas that has been cleaned up to utility specs for pipeline injection or use in vehicles as CNG
- **RG:** possible future term for RNG, shortened to “Renewable Gas”

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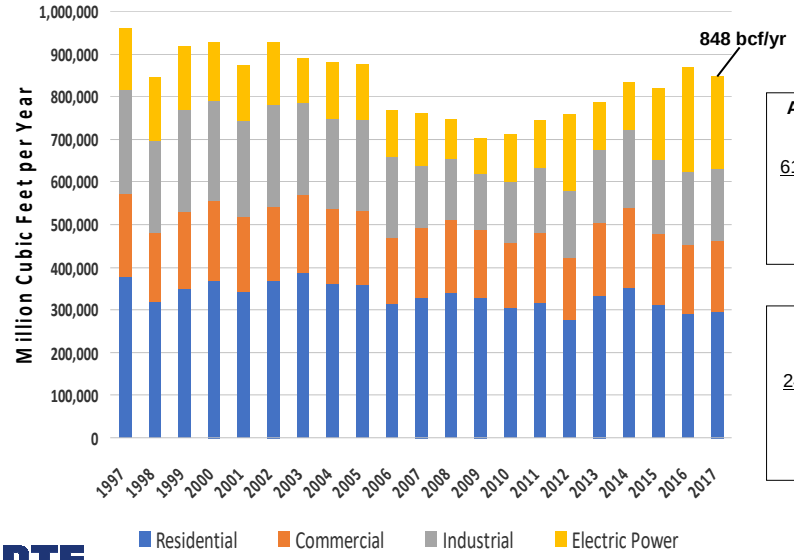
anaerobic digester

Organics

removed.

We can make 25% RNG by 2040 in Michigan

However, it would be difficult to make more than 10% RNG for all sectors, today



Aggressive Scenario

61.9 bcf RNG
848 bcf

= 7.3 %

Maximum Scenario

243 bcf RNG
848 bcf

= 28.7 %

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Source: www.eia.gov/dnav ng/ng_cons_sum_dcu_SMI_a.htm

We can make some assumptions about the future…

- Coal plants will retire
- New natural gas plants will be more efficient
- Many cars switch to electric EV's
- 2040 electric supply:
    - *40% renewable, 40% gas, 20% nuclear*
- Energy efficiency will reduce load
    - *Assume -1.5% per year*
- Let's look at RNG to residential, commercial, industrial sectors only (our natural gas customers)
- Economic growth ?

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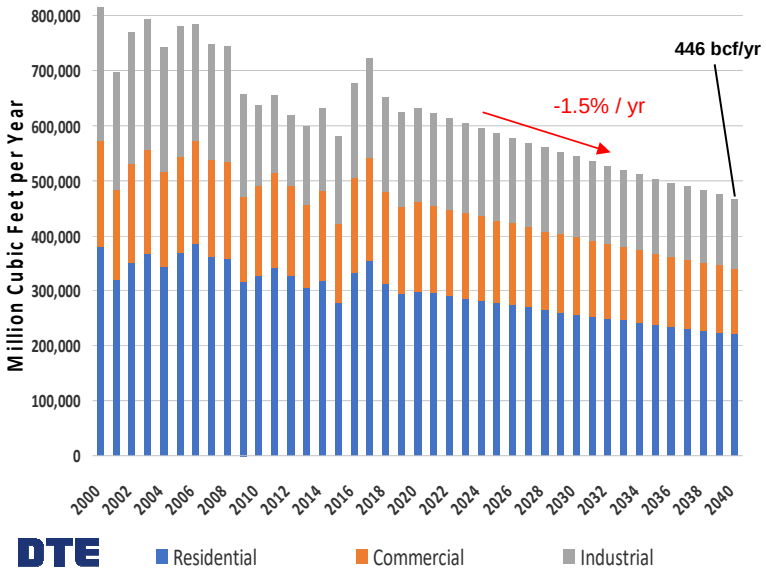
Looking forward to 2040 at only residential, commercial and industrial, we can more easily make 25%



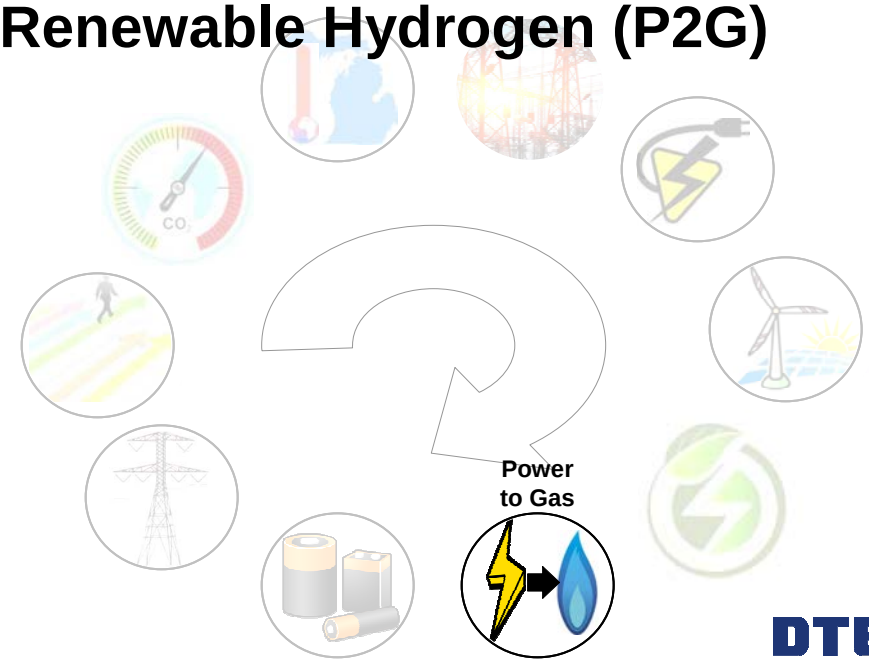
Aggressive Scenario

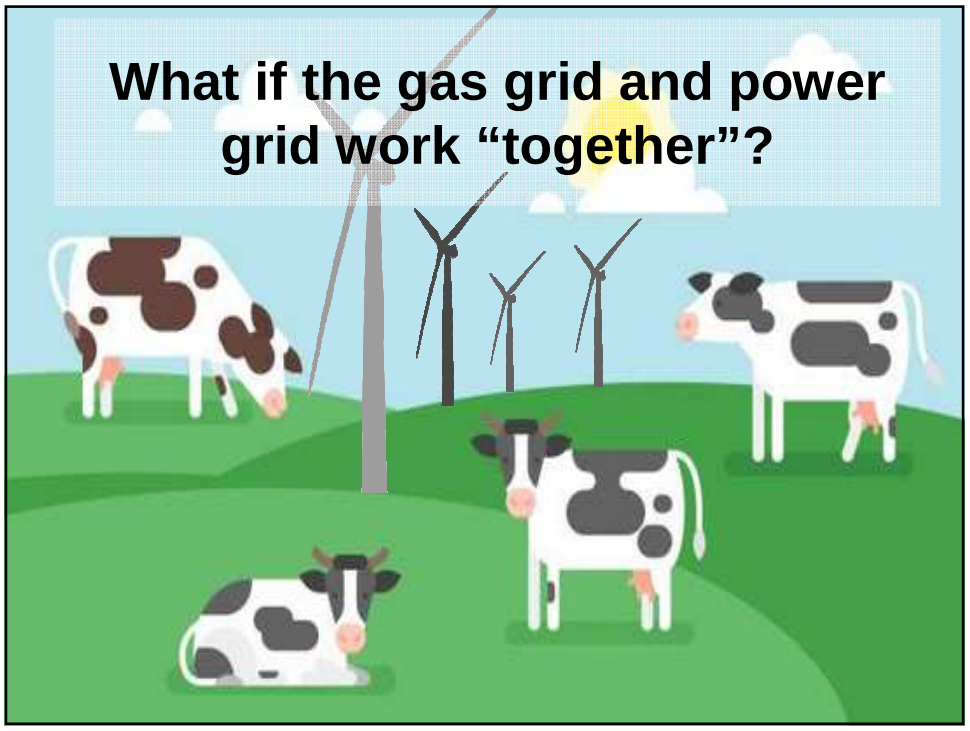
61.9 bcf RNG
446 bcf
= 13.9 %

Maximum Scenario

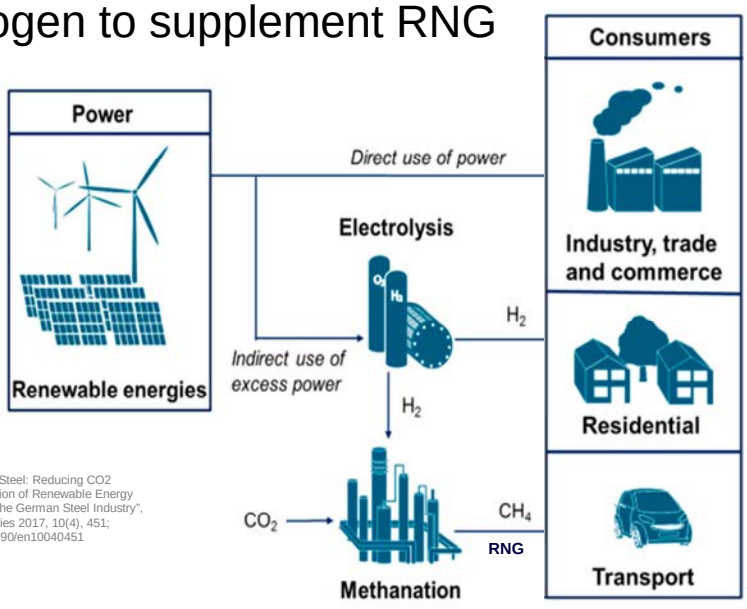
243 bcf RNG
446 bcf
= 54.5 %

Renewable Hydrogen (P2G)





Power to Gas (P2G) creates renewable hydrogen to supplement RNG



Source: “Power-to-Steel: Reducing CO2 through the Integration of Renewable Energy and Hydrogen into the German Steel Industry”, A.Otto, et.al., Energies 2017, 10(4), 451; https://doi.org/10.3390/en10040451

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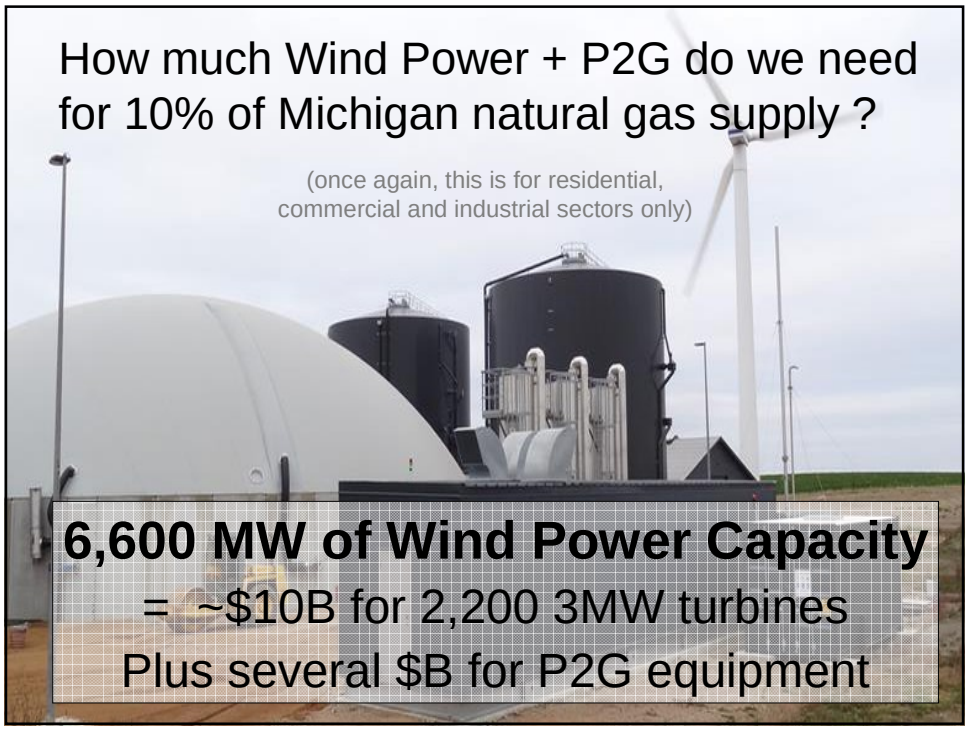
How much Wind Power + P2G do we need for 10% of Michigan natural gas supply ?

(once again, this is for residential, commercial and industrial sectors only)

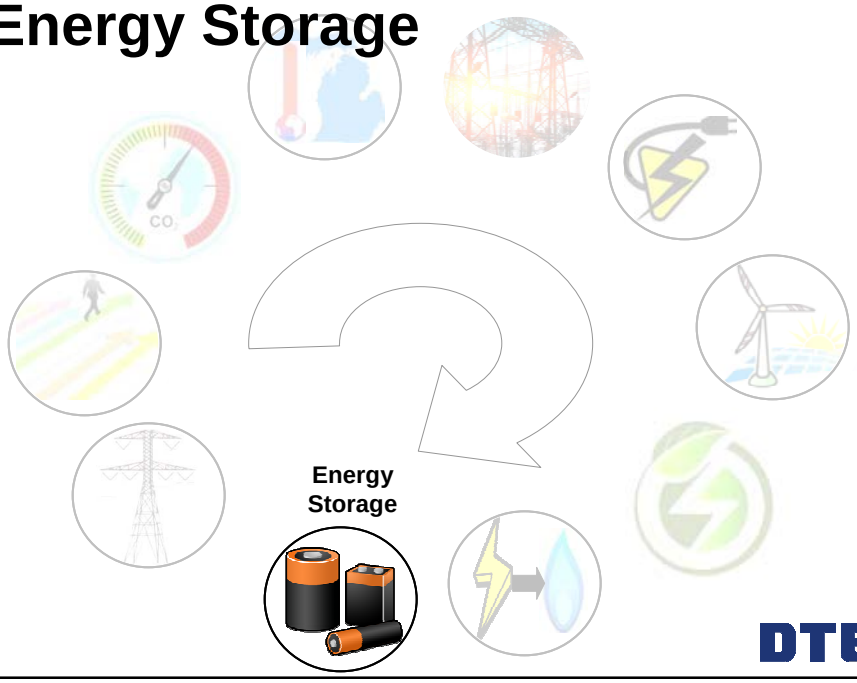


6,600 MW of Wind Power Capacity

= ~$10B for 2,200 3MW turbines

Plus several $B for P2G equipment

Energy Storage



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The world's largest battery is 0.129 GWh

Tesla's 100 MW / **129 MWh** installation in South Australia is the most powerful battery system in the world, as of 2019.

Other Utility-Scale Energy Storage

- **Pumped hydro**
- **Thermal energy**
  (molten salt at solar thermal plants)
- **Compressed air storage**
  (used with natural gas turbines)
- **Flow batteries** (vanadium redox)

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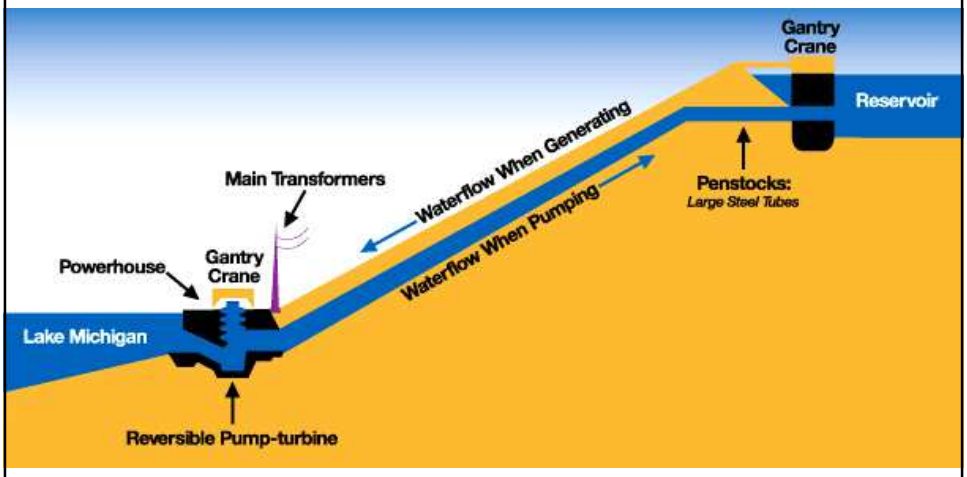
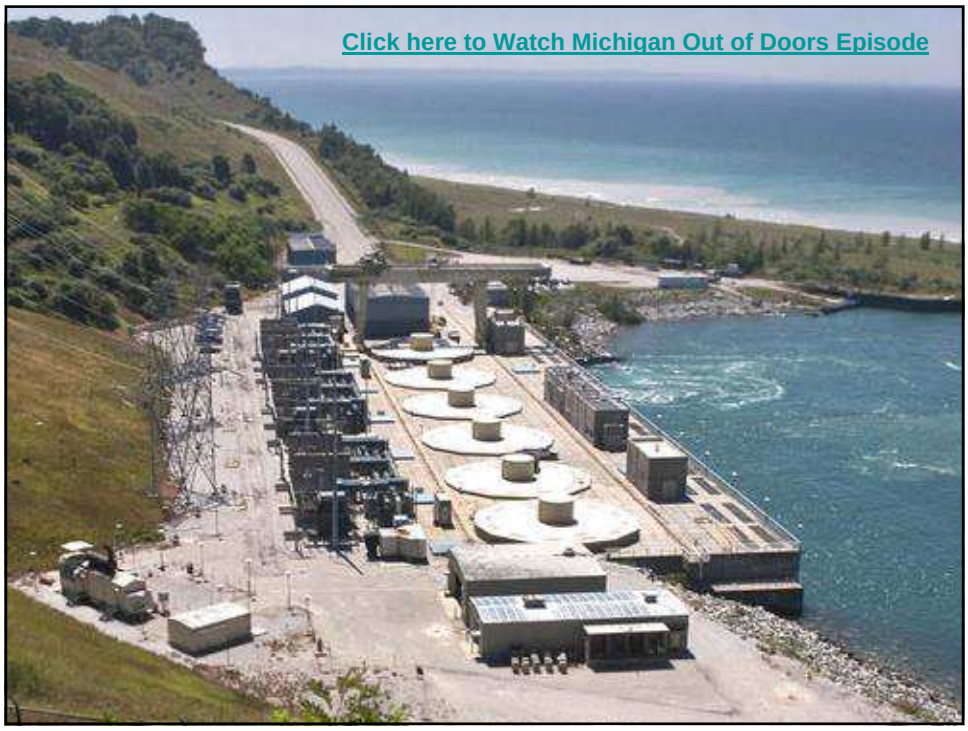
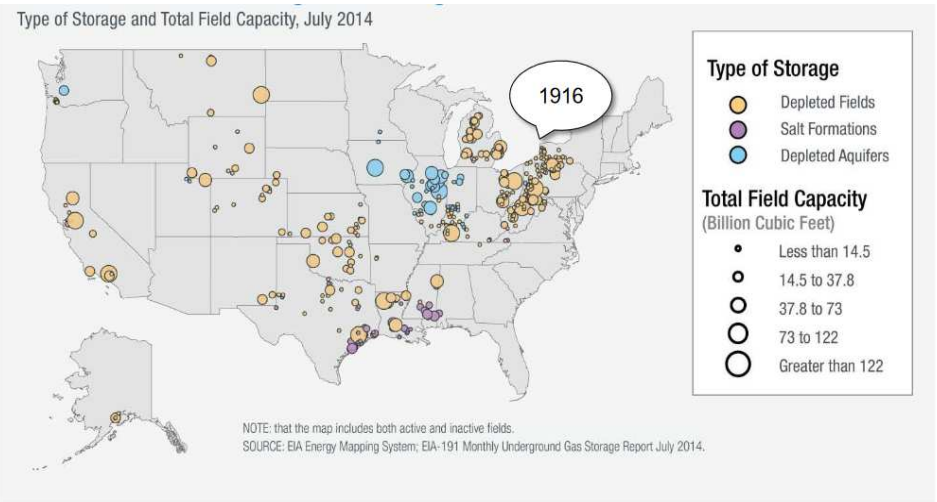
When upgrades are completed to Ludington, the capacity will be 2.17 GW for 8 hrs = 18.4 GWh



At night, the reservoir is replenished using off-peak grid power. During the day, the reversible pump-turbines generate electricity as water is released from the reservoir.

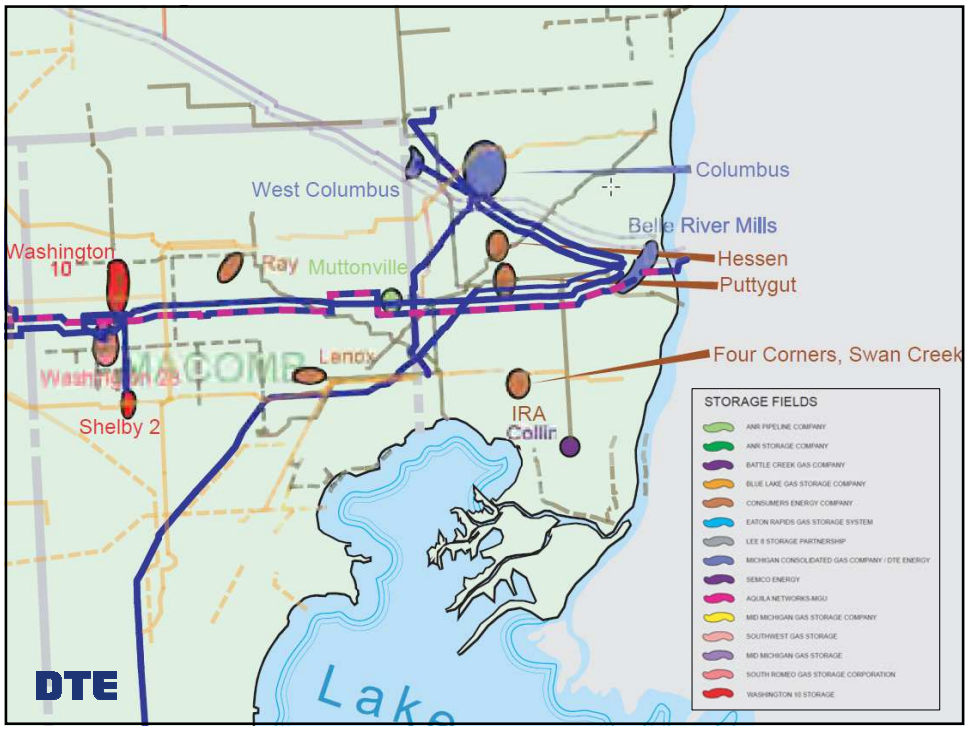


Natural Gas has significant underground storage in the United States



DTE


DTE
Lake Huron
Lake Michigan
CANADA
INDIANA
OHIO
MAJOR PIPELINES
STORAGE FIELDS
ANR PIPELINE COMPANY
ANR STORAGE COMPANY
BATTLE CREEK GAS COMPANY
BLUE LAKE GAS STORAGE COMPANY
CONSUMERS ENERGY COMPANY
EATON RAPIDS GAS STORAGE SYSTEM
LEE 8 STORAGE PARTNERSHIP
MICHIGAN CONSOLIDATED GAS COMPANY / DTE ENERGY
SEMCO ENERGY
AQUILA NETWORKS-MGU
MID MICHIGAN GAS STORAGE COMPANY
SOUTHWEST GAS STORAGE
MID MICHIGAN GAS STORAGE
SOUTH ROMEO GAS STORAGE CORPORATION
WASHINGTON 10 STORAGE


West Columbus
Columbus
Belle River Mills
Hessen
Puttygut
Washington 10
Ray
Muttonville
Lenox
Four Corners, Swan Creek
Shelby 2
IRA
Collin
DTE
STORAGE FIELDS
ANR PIPELINE COMPANY
ANR STORAGE COMPANY
BATTLE CREEK GAS COMPANY
BLUE LAKE GAS STORAGE COMPANY
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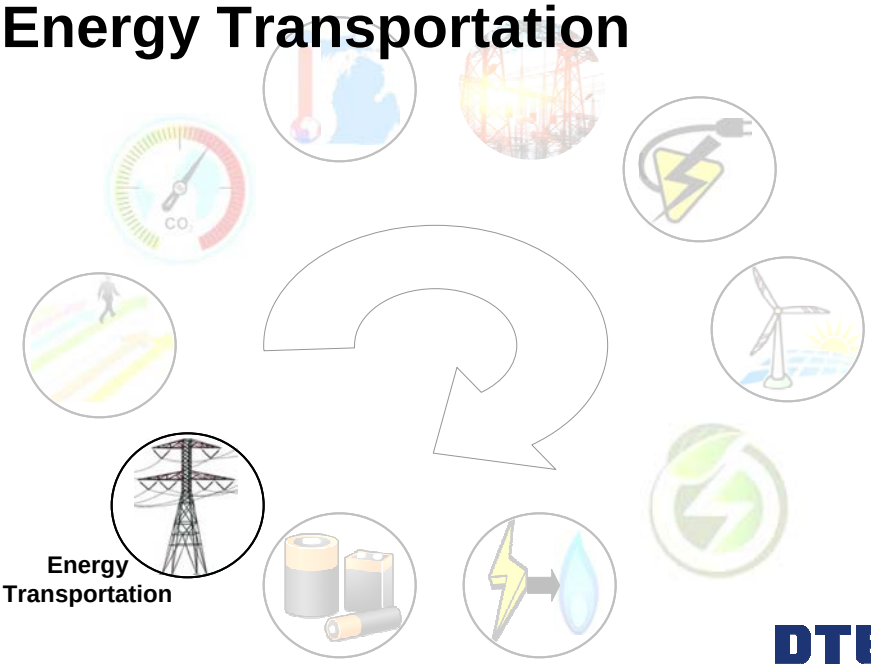
MID MICHIGAN GAS STORAGE COMPANY
SOUTHWEST GAS STORAGE
MID MICHIGAN GAS STORAGE
SOUTH ROMEO GAS STORAGE CORPORATION
WASHINGTON 10 STORAGE

Michigan natural gas storage totals 207 GWh of energy in existing assets

Owner	BCF	GWh
DTE Gas	139	42.4
DTE Midstream	91	27.7
DTE Subtotal	**230**	**70.1**
State Total	680	207.3

Add only 10% RNG: = ~20 GWh stored renewable energy, in existing infrastructure

Energy Transportation



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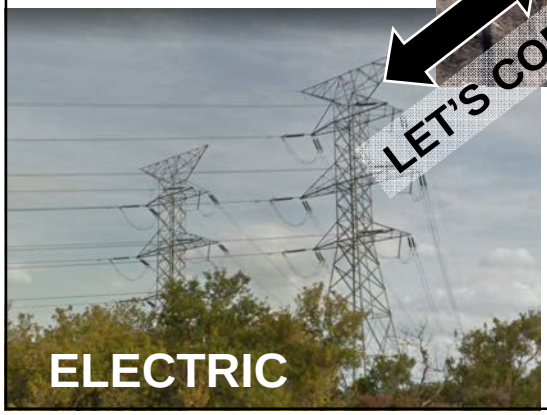
345 kV transmission from Monroe Power Plant. If at full plant 3.4 GW capacity, each set of the four 3 phase lines could carry 850 MW at 1,420A

LET'S COMPARE

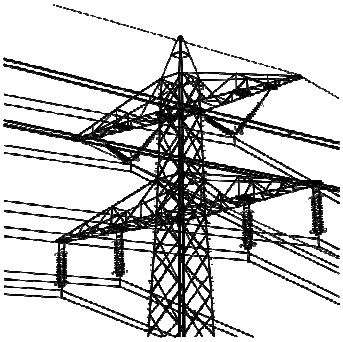


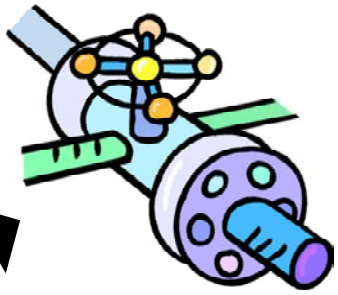
600 psig, 30 inch pipeline, 1,000 ft/min = 88 GWh / day gas

Gas pipelines transport vast amounts of energy

3.4 GW

Four sets of 3 phase, 345 kVA high voltage lines: 1,420VAC/ph





3.7 GW

600 psig underground 30 inch gas transmission line

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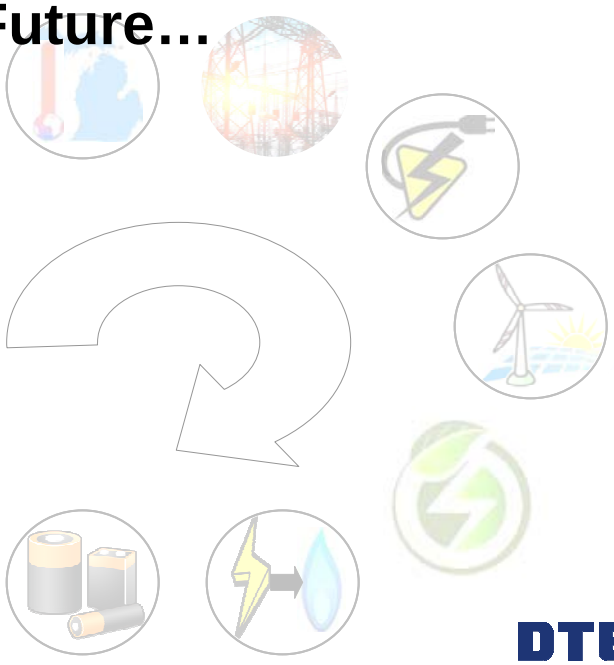
Into the Future…

The Future?



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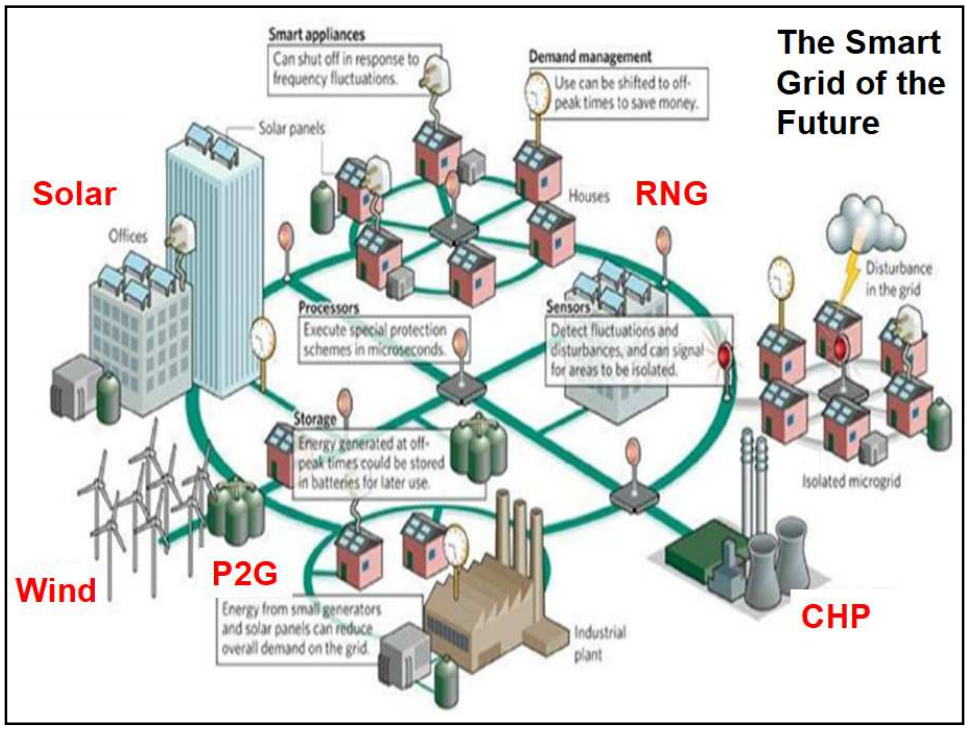
Here is just one examp
Carbon Capture that is

1. A portion of flue gas is diverted to **cleanO2**

5. Soda as

5. Carbonates are collected from the system for use or sale (CleanO2 is presently making soap with the byproduct)



Thank you

Questions?

DTE

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Handout to accompany presentation titled ***Data Driven Low Carbon Energy for Sustainability,*** Low Carbon Solutions for Michigan in 2019 and Beyond

James Leidel
DTE Energy, Gas Major Accounts
October 2019

ELECTRIFICATION HEADING:

Slide Title: It would be very difficult and costly to fully electrify Michigan fossil fuel usage

	GWh
Electric power, fossil fuel usage	199,648
Est. generation to fully electrify	457,614

	GW
Approx. electric summer peak	20
Approx. January natl gas peak	96

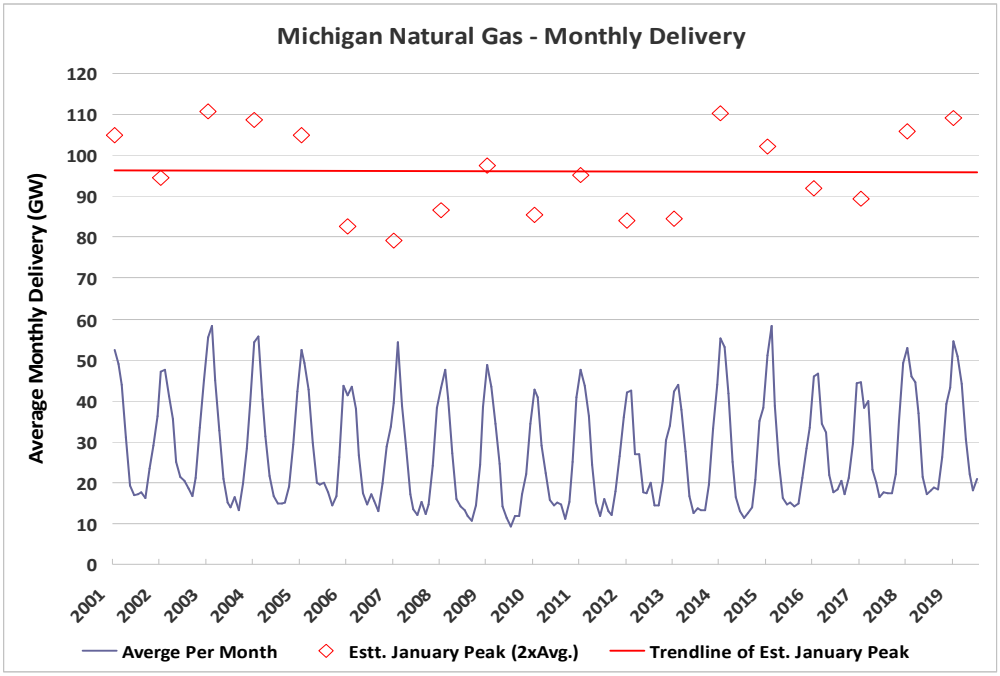
	Total Fossil Fuel GWh	Estimated Sector Overall Efficiency %	Estimated Energy Load Served GWh	Alternative Solar, Wind & Storage System Efficiency %	Estimated Renewable Electric Supply Required GWh
RESIDENTIAL	102,638	81%	83,137	75%	110,849
COMMERCIAL	56,360	84%	47,342	75%	63,123
INDUSTRIAL	98,066	79%	77,472	75%	103,296
TRANSPORTATION	215,328	35%	75,365	75%	100,487
ELECTRIC POWER	199,648	30%	59,894	75%	79,859
TOTALS	**672,040**		**343,210**		**457,614**

Explanation
Fossil fuel use per sector is totalized, then the estmated sector overall efficiency of fuel to heat, fuel to mechanical, or fuel to electric is applied
This estimatest the load served per sector: either thermal, motive power (mechanical), or electricity.
Storage batteries loose energy upon charging and discharging, and some trasmission losses are also present in a future renewable powered grid.
The alt. energy efficiency is applied to the sector energy load estimate, and a required solar & wind total GWh is estimated.

Result: 456,614 GWh of solar and wind generation is needed to replace all Michigan fossil fuel

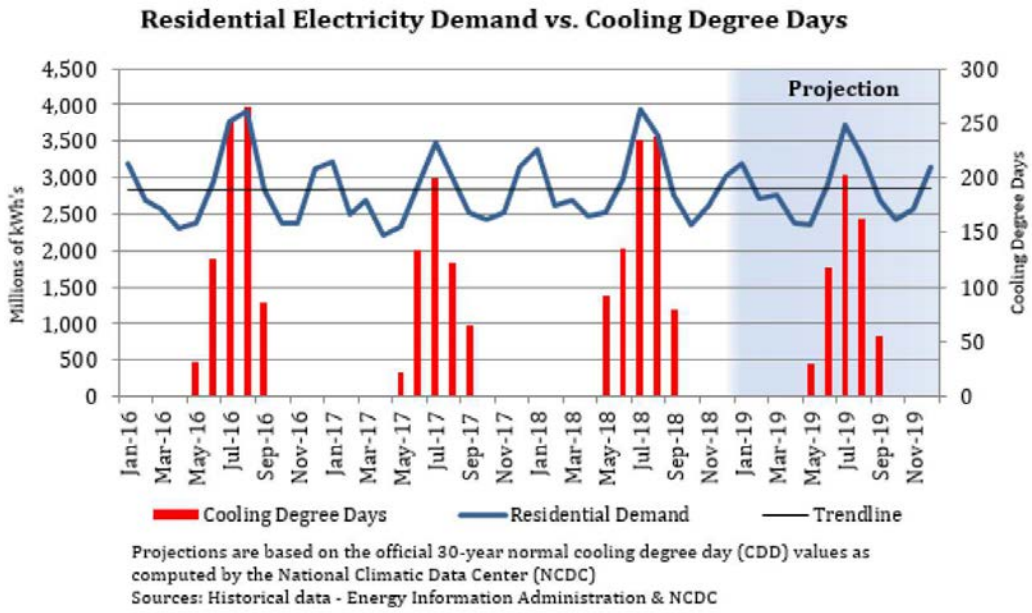
Energy Data Source: 2017 US DOE, Energy Information Administration

Estimate of Michigan natural gas peak flow of 96 GW



Source: 2017 US DOE Data, Energy Information Administration, ng_cons_sum_dcu_smi_m.xls, http://www.eia.gov/dnav/ng/ng_cons_sum_dcu_smi_m.htm, 9/30/2019

MICHIGAN ELECTRIC PEAK: "In 2018, the actual electrical demand for bundled customers in Consumers Energy's service territory peaked at 7,568 MW on July 5, and in DTE's service territory at 11,418 MW on September 5." Source: "Michigan Energy Appraisal Summer Outlook 2019", Michigan Public Service Commission (June 2019).



Slide Title: ***Residential Heating Example:***
Natural gas solutions have significantly lower carbon footprints (in Michigan)

Residential Home Annual Energy Loads

Loads	***Source***	***Units***	***Avg per year***	***Avg per month***
Electricity plug loads & A/C	grid electric	kWh	10,000	833.3
Space heating	natural gas	MMBTU	100	8.3
Domestic water heating	natural gas	MMBTU	15	1.3

Carbon Intensity of Energy Sources

Natural gas	117	lb / MMBTU
Electric grid	2.15	lb / kWh

https://newlook.dteenergy.com/wps/wcm/connect/dte-web/home/community-and-news/common/environment/fuel-mix

Heating and Power Generation Equipment Efficiencies

Electric heat pump	3.0	COP avg heating	
Natural gas furnace std eff.	82%	efficiency	
Natural gas furnace high eff.	95%	efficiency	
Natural gas heat pump	1.2	COP avg heating	
micro CHP thermal efficiency	55%	thermal efficiency	
micro CHP electrical efficiency	30%	electrical efficiency	
micro CHP electrical capacity	2.5	kW AC	assume runs continuous for 5 month htg. season

Annual Energy Consumption

	Space Ht Load MMBTU	mCHP Nat Gas MMBTU	Furnace Nat Gas MMBTU	Total Nat Gas MMBTU	Space Heating kWh	Plug Loads kWh	mCHP output kWh	Total Grid kWh
Electric heat pump	100	0	0	0.0	9,769	10,000	0	19,769
Natural gas furnace std eff.	100	0	122.0	122.0	0	10,000	0	10,000
Natural gas furnace high eff.	100	0	105.3	105.3	0	10,000	0	10,000
Natural gas heat pump	100	0	83.3	83.3	0	10,000	0	10,000
micro CHP + high eff furnace	100	102.36	46.0	148.4	0	10,000	9,000	1,000

Annual CO2 Production

	Grid Electric tons CO2	Natural Gas tons CO2	TOTAL tons CO2	Reduction from HP %	Year 2030 Grid Electric tons CO2	Year 2030 TOTAL tons CO2	Year 2030 (+/-) from HP %
Electric heat pump	42,504	0	42,504		21,252	21,252	
Natural gas furnace std eff.	21,500	14,268	35,768	-15.8%	10,750	25,018	17.7%
Natural gas furnace high eff.	21,500	12,316	33,816	-20.4%	10,750	23,066	8.5%
Natural gas heat pump	21,500	9,750	31,250	-26.5%	10,750	20,500	-3.5%
micro CHP + high eff furnace	2,150	17,358	19,508	-54.1%	1,075	18,433	-13.3%

The 2030 electric grid CO2 goal is to be reduced by 50% (this is the DTE Electric plan)

Slide Title: ***1 MW Power Generation Example:***
Natural gas CHP provides lowest investment per tone of CO2 reduced

Per MW of Installed Capacity

Technology	**Installed Cost**	**Capacity Factor**	**Yield**	**CO2 Reduction**	**CO2 Reduction**	**CapEx Required**
	$M per MW	%	MWh per yr	% compared to grid	Tons CO2 per yr	$ per (ton CO2/yr)
Solar	$1.50	14.5%	1,270	100.0%	1,366	$1,098
Wind	$1.80	35.0%	3,066	100.0%	3,297	$546
Battery Storage	$2.43	n/a	n/a	n/a	n/a	n/a
Solar + Battery	$3.93	14.5%	1,270	100.0%	1,366	$2,877
Wind + Battery	$4.23	35.0%	3,066	100.0%	3,297	$1,283
CHP	$2.00	95.0%	8,322	45.0%	4,027	$497

Technology	**Dispachable?**	**Provides Backup?**	**Location?**	**Provides Heat Energy?**
Solar	no	no	on-site	no
Wind	no	no	remote	no
Battery Storage	yes	yes	on-site	no
Solar + Battery	yes	yes	on-site	no
Wind + Battery	yes	yes	remote	no
CHP	yes	yes	on-site	yes

RENEWABLE HYDROGEN (P2G) HEADING:

Slide Title: How much Wind Power + P2G do we need for 10% of Michigan natural gas supply ?

(excluding utility electric power sector)

Wind Energy Farms
6,600 MW
LCOE: $0.035 / kWh

Cost in $US
LCOE = levelized cost of energy
Assume a 35% capacity factor

$\eta_1 = 80\%$

P2G
4.0 kWh / Nm^3 H2
113 kWh / MCF H2

(water in, H2 & O2 out)

35.31 cubic feet per normal cubic meter (Nm3)
MCF = 1,000 cubic feet

H_2

$\eta_2 = 80\%$

Methanation
4.0 Nm^3 H2 / Nm^3 CH4
4.0 MCF H2 / MCF CH4

(H2 & C in, CH4 & H2O out)

$CO_2 + 4H_2 \longrightarrow CH_4 + 2H_2O$

CH_4

$\eta_3 = 85\%$

Compression and Pipeline
44.6 BCF / year
$15.80 / MCF
(electric cost only)

Graphic: Hydrogenics

$\eta_{total} =$

$\eta_1 \times \eta_2 \times \eta_3$

~ 54%

DTE