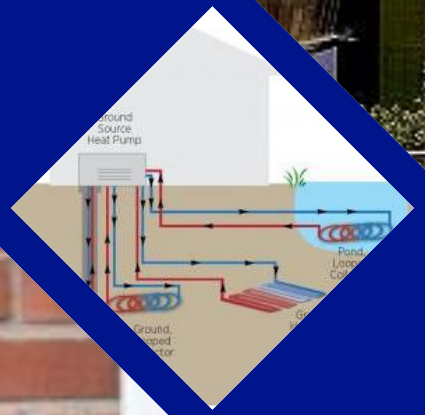
Heat Decarbonization in the Northeast



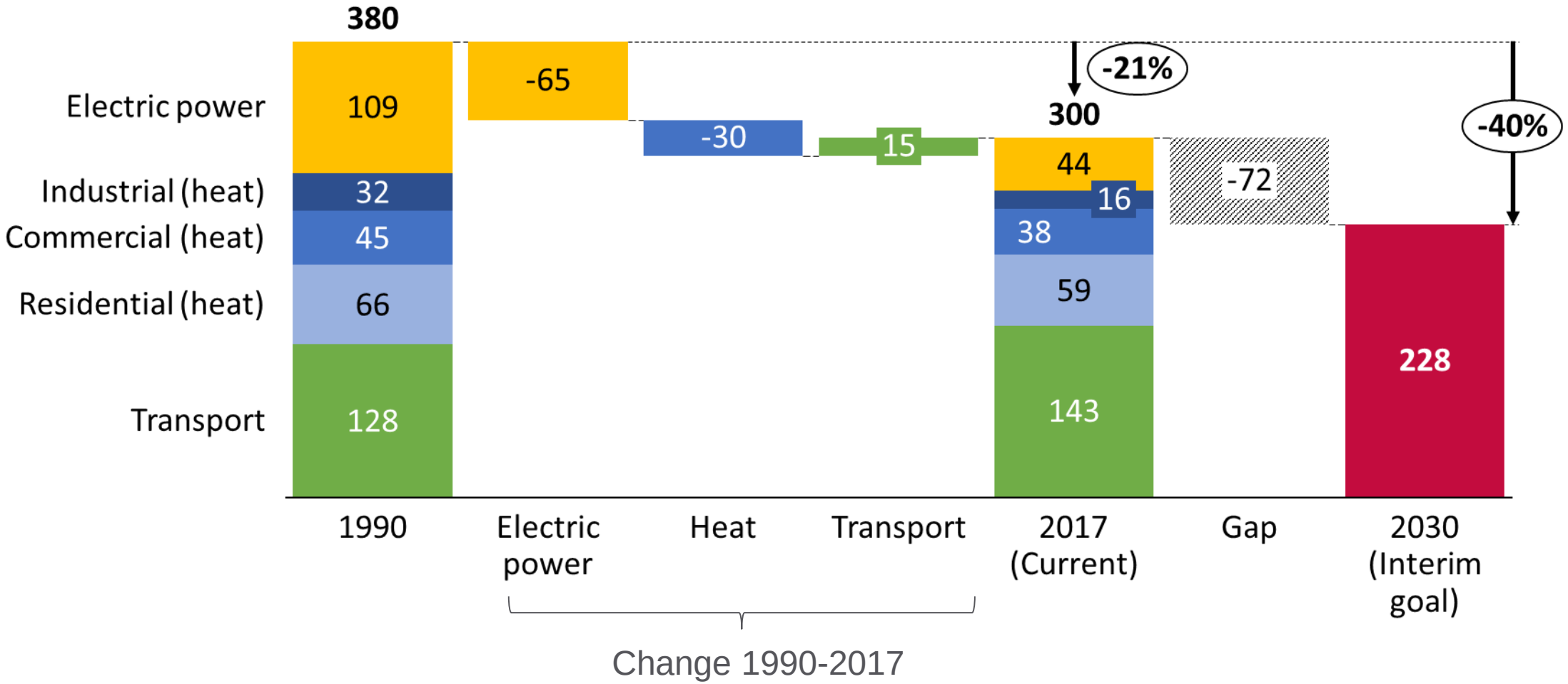
AEE
6 November 2019

Mackay Miller
Director, US Strategy
National Grid

nationalgrid

The US Northeast has reduced energy-related carbon emissions by 21% since 1990; significant reductions from heat and transport to reach net zero

US Northeast energy-related CO_2 emissions[1] and change by sector (million metric tons CO_2)



1 Includes only emissions from fossil fuel combustion in the energy sector, which account for ~85% of economy-wide emissions, i.e. excludes agriculture, land use. Sources: US DOE Energy Information Administration.

There are three main sources of energy-related GHG emissions in the Northeast

Electric power generation

Electricity generating plants, mostly large-scale gas-fired units. Limited coal- and oil-based plants remain

Transport

Mainly light-duty (passenger) cars and trucks, and medium- and heavy-duty vehicles; aviation and shipping

Heat (buildings and industry)

Space heating services in residential and commercial buildings, and process heat in industrial settings

National Grid's Northeast Decarbonization Pathway

Elements of the National Grid Northeast Decarbonization Pathway

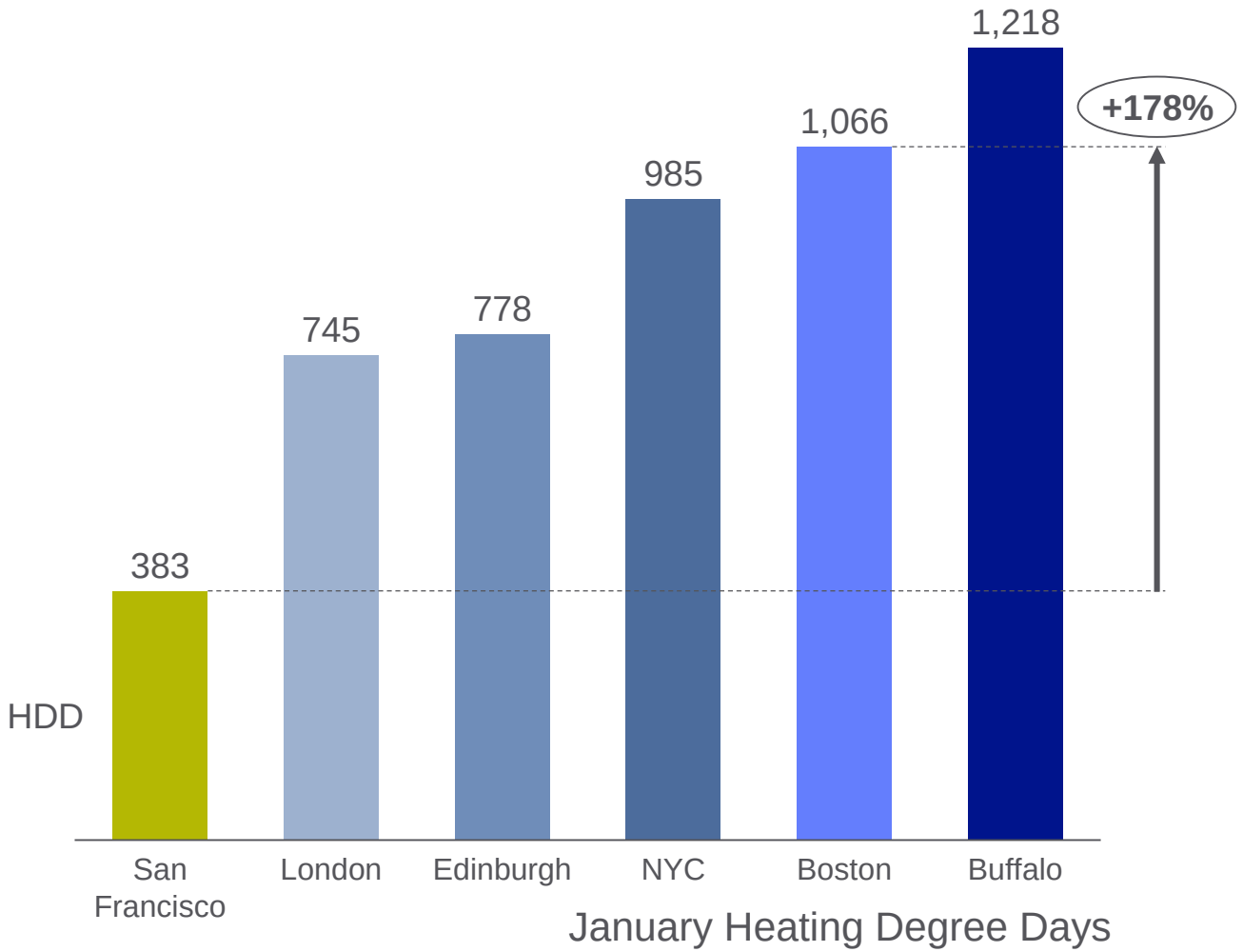
	40% x 2030	80% x 2050
Power	▪ 67% zero-carbon electricity supply, supported by a large increase in renewables (vs. 45% in 2017)	▪ 100% zero-carbon electricity supply, utilizing: - Large-scale renewables - Zero-carbon "firm" capacity, e.g. hydro, nuclear, gas with carbon capture and storage and interconnections (Quebec) - Inter-seasonal energy storage
Transport	▪ >10 million light-duty (passenger) electric vehicles on roads (vs. <75k in 2017)	▪ >20 million light-duty (passenger) vehicles (100% of the fleet) ▪ Low-carbon technology use in medium and heavy duty vehicles (electric or natural gas) ▪ Efficiency improvement in aviation, shipping
Heat	▪ 2x rate of energy efficiency retrofits ▪ 3x rate of oil-to-gas heating conversions ▪ 10x scale up of oil-to-electric heating conversions	▪ Deepen energy efficiency investment, especially in home insulation ▪ Decarbonize natural gas supply for heating, e.g. biomethane, hydrogen blending ▪ Use hybrid natural gas / electric heating

The Northeast climate warrants tailored heat solutions

Heat demand in Boston exceeds that of San Francisco by **178%**

California heat decarbonization policy will not be our template for Northeast

The Northeast will need to develop its own policy and technical approach to heat decarbonization.



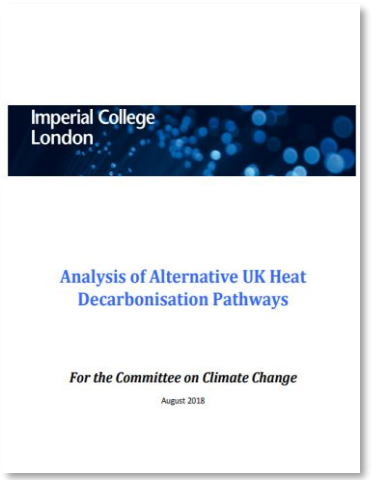
Fahrenheit-based 5-year-average (2013 to 2017) heating degree days for January (base 65F).
Source:www.degreedays.net (using temperature data from www.wunderground.com)

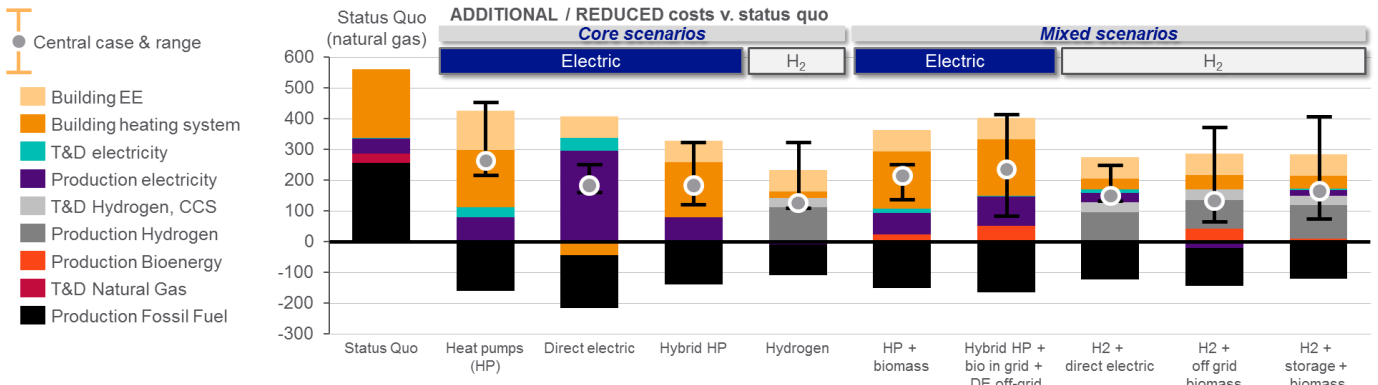
The UK is leading the way in rigorous analysis of heat decarbonization

Since 2012, the UK government has commissioned a sustained analytical program around low-carbon heat.

Major studies in 2018 (commissioned by the *Committee on Climate Change* and the *National Infrastructure Commission*) tested total system costs of full electrification vs. hybrid vs. hydrogen pathways.

Even in the warmer UK climate, the lowest cost pathway is uncertain as of yet

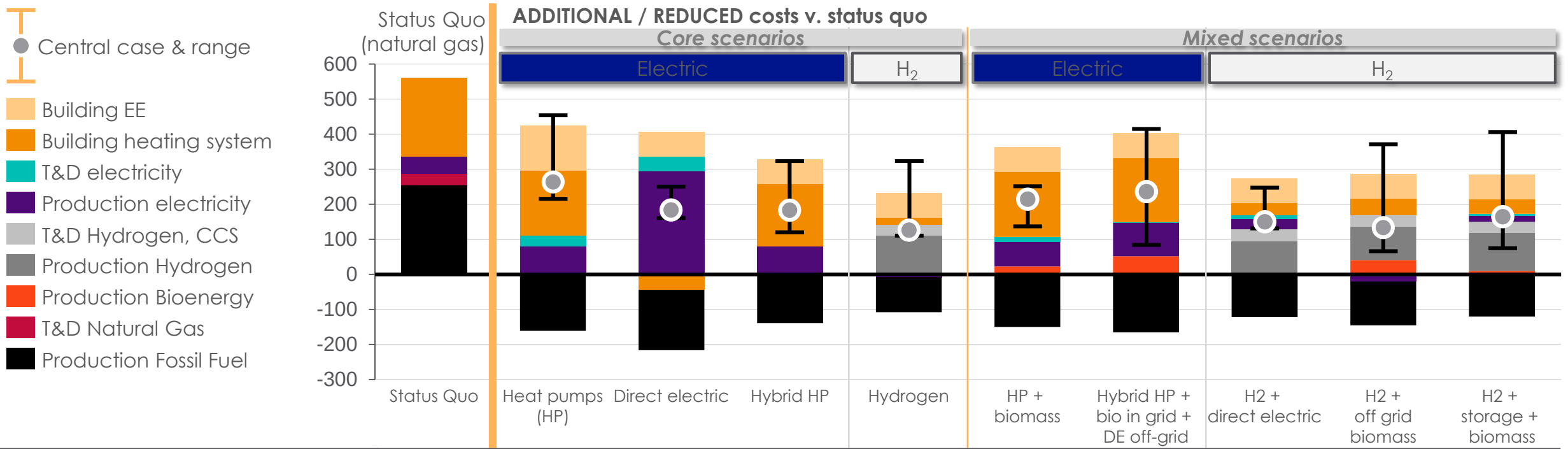




Heat as % GDP[1] (1.2% in 2015)			0.9%	0.9%	0.8%	0.9%				
Annual GHG emissions in 2050 ($MtCO_2e$)[4]		~100	5-10	10-15	20-25	20-25	5-10	10-15	10-15	10-15	0-(5)
Major uncertainty drivers	EE retrofit requirement		X				X	X			
	HP / electric heater unit cost		X	X	X		X	X			
	Grid reinforcement cost		X	X			X				
	Fuel cost: electricity			X							
	In-building retrofit cost					X			X	X	X
	Production: hydrogen					X			X	X	X
	CCS; H_2 safety & consumer[2]					X			X	X	X

Full system costing study [UK]: all pathways more expensive than status quo however heating cost seen to decline as % GDP regardless; lowest cost pathway uncertain as of yet

Cost comparison of different prospective UK heat solutions
£B, cumulative discounted system costs to 2050

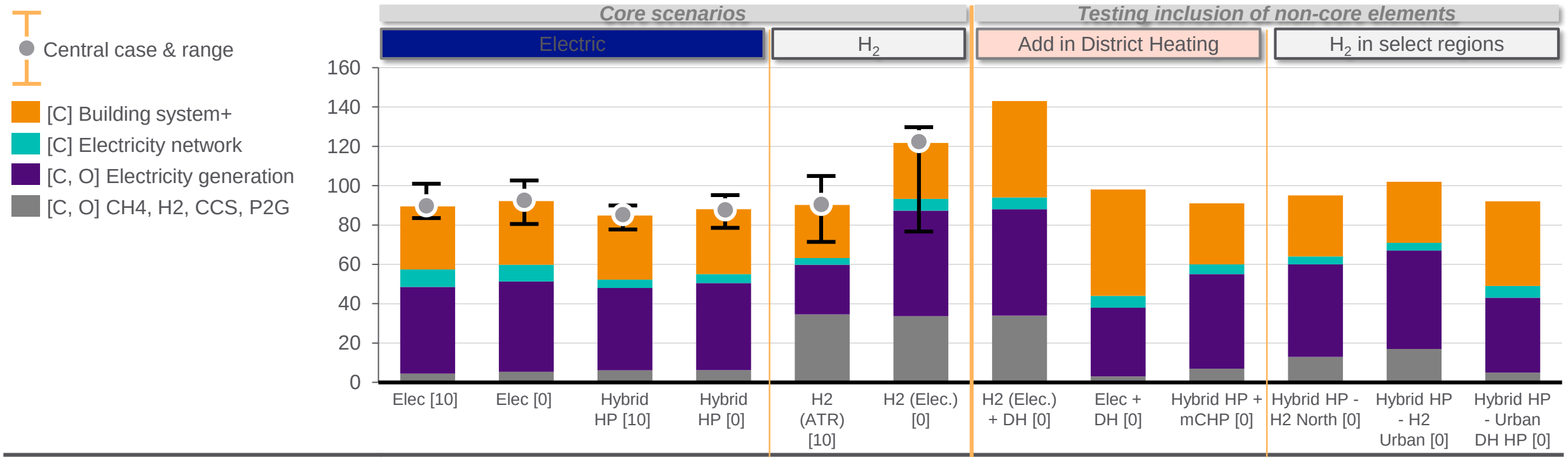


Heat as % GDP[1] (1.2% in 2015)			**0.9%**	**0.9%**	**0.8%**	**0.9%**					
Annual GHG emissions in 2050 (MtCO2e)[4]		**~100**	**5-10**	**10-15**	**20-25**	**20-25**	**5-10**	**10-15**	**10-15**	**10-15**	**0-(5)**
Major uncertainty drivers	**EE retrofit requirement**		X				X	X			
	HP / electric heater unit cost		X	X	X		X	X			
	Grid reinforcement cost		X	X			X				
	Fuel cost: electricity			X							
	In-building retrofit cost					X			X	X	X
	Production: hydrogen					X			X	X	X
	CCS; H_2 safety & consumer[2]					X			X	X	X

[1] cumulative cost to 2050 as % of GDP to 2050, NOT DISCOUNTED; [2] includes not just cost uncertainties but also readiness uncertainties; [3] central case assumes consumer behaviour supports a diversity factor of 2.4 v. Worst case assumes diversity factor of 1. [4] does not factor indirect GHG emissions e.g., upstream methane leaks, flaring, venting
SOURCES: Element Energy & E4tech for UK National Infrastructure Commission (2018)

Appendix B: Full system costing [UK] – study #2 – second study similarly concludes that given current uncertainties, the lowest cost pathway is not clear yet

Cost comparison of different prospective UK heat solutions
£B / year; annual system costs in 2050

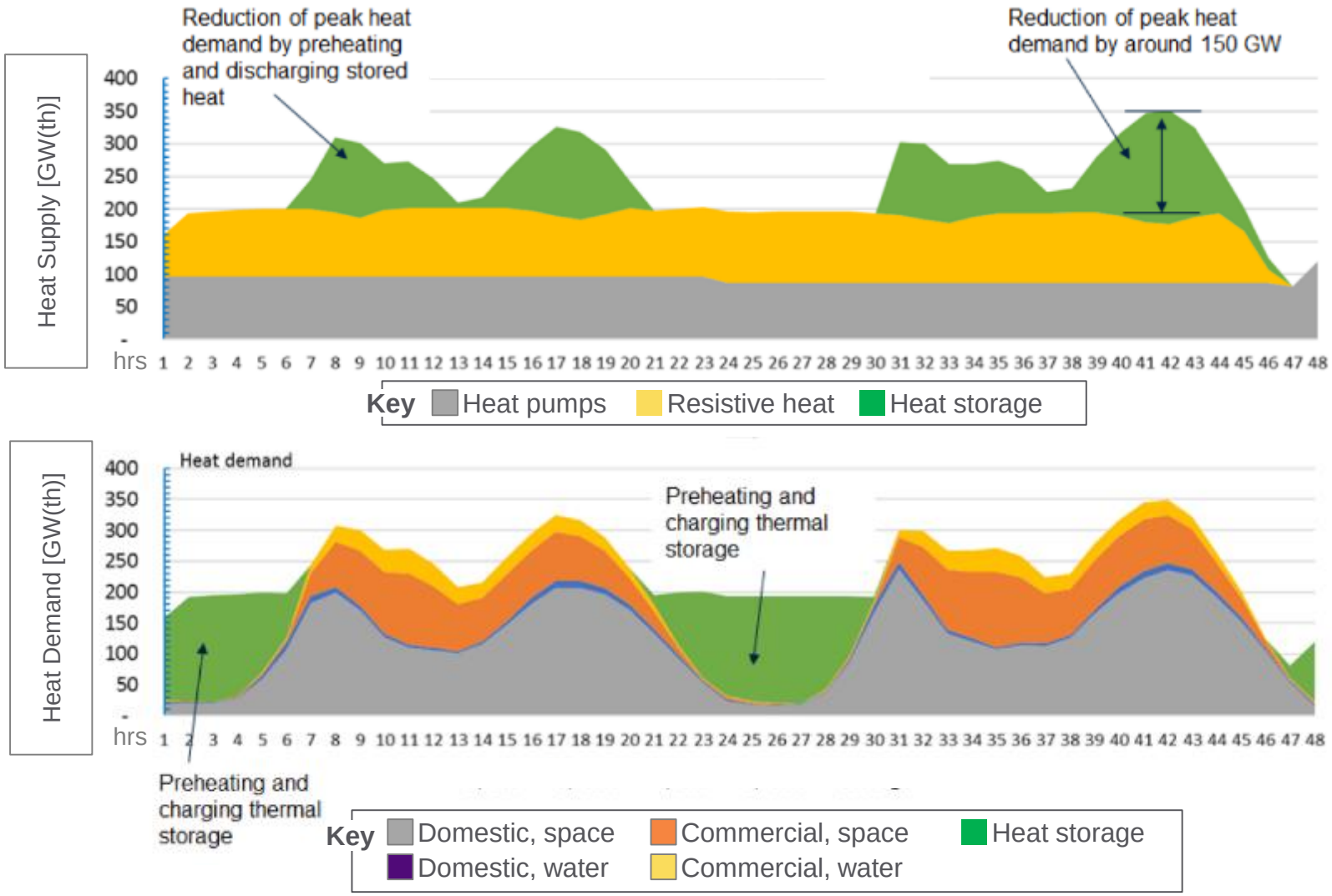


		Elec [10]	Elec [0]	Hybrid HP [10]	Hybrid HP [0]	H2 (ATR) [10]	H2 (Elec.) [0]	H2 (Elec.) + DH [0]	Elec + DH [0]	Hybrid HP + mCHP [0]	Hybrid HP - H2 North [0]	Hybrid HP - H2 Urban [0]	Hybrid HP - Urban DH HP [0]
Annual GHG emissions in 2050 (MtCO2e)		**10**	**0**	**10**	**0**	**10**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Major uncertainty drivers[1]	**H_2 import; ATR capture rate**	X	X										
	CapEx of low-carbon gen.		X	X	X	X	X						
	Flexibility of power systems			X	X		X						
	Fuel prices	X											
	Heating appliance cost	X	X	X	X	X	X						

SOURCES: Imperial College of London for UK Committee on Climate Change(2018); [1] uncertainties for 10MtCO2e cases drawn from 30Mt cases in paper given close; uncertainty ranges exclude consideration of discount rate (impact roughly equal across scenarios), CO2e target (factored into each scenario), heating demand (roughly equal impact across scenarios) proximity of overall costs for the two cases; only references the more significant drivers of uncertainty in the paper

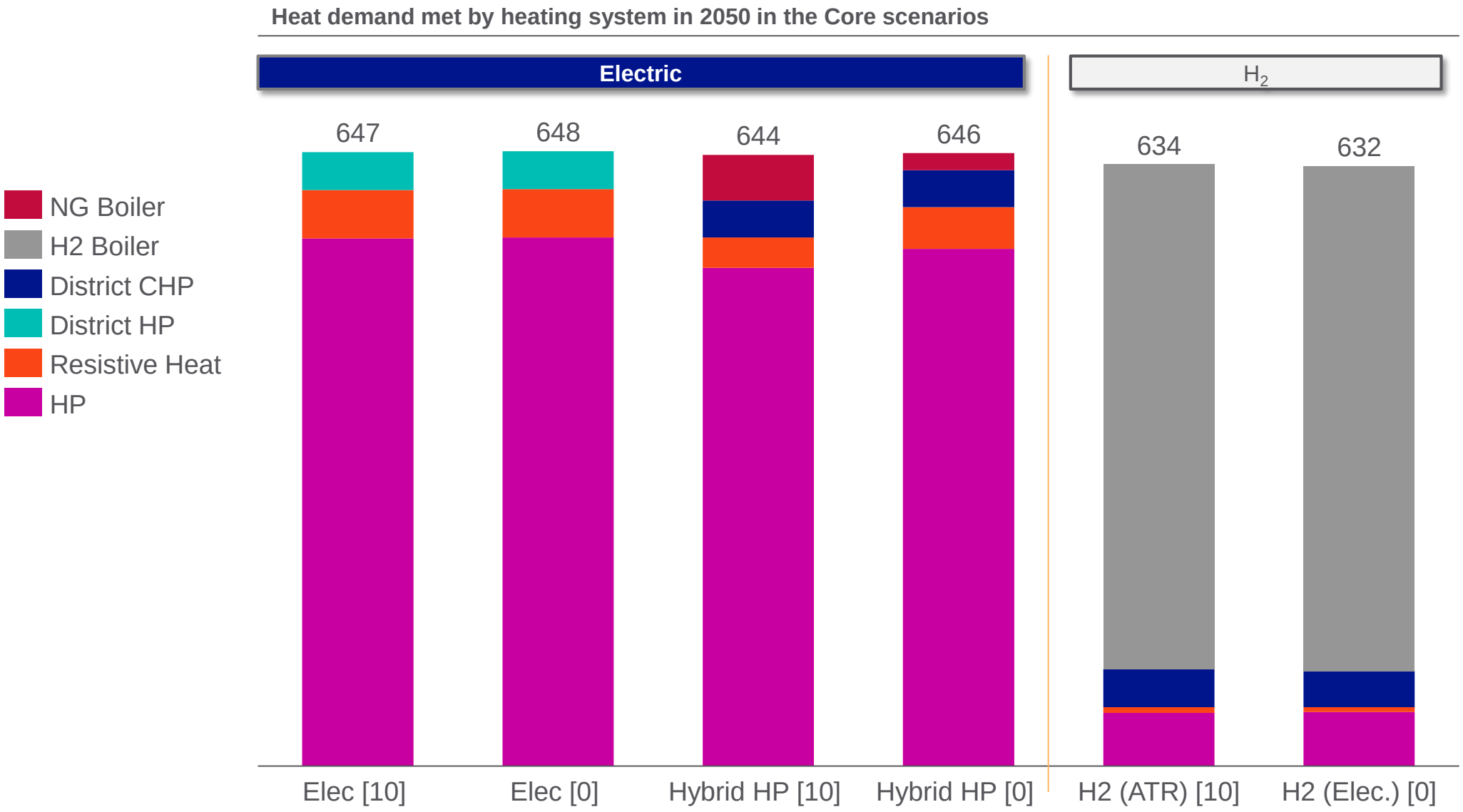
Solving for peak: pre-heating and thermal storage can help reduce peaks, especially within day (example)

Flexibility provided by thermal storage and preheating (example over two days)



SOURCES: Imperial College of London for UK Committee on Climate Change(2018)

Solving for peak: [1] hybrids leverage low utilisation gas boiler; [2] hydrogen pathway requires sufficient stored H_2 as well as H_2 production to supply boilers in homes during peak



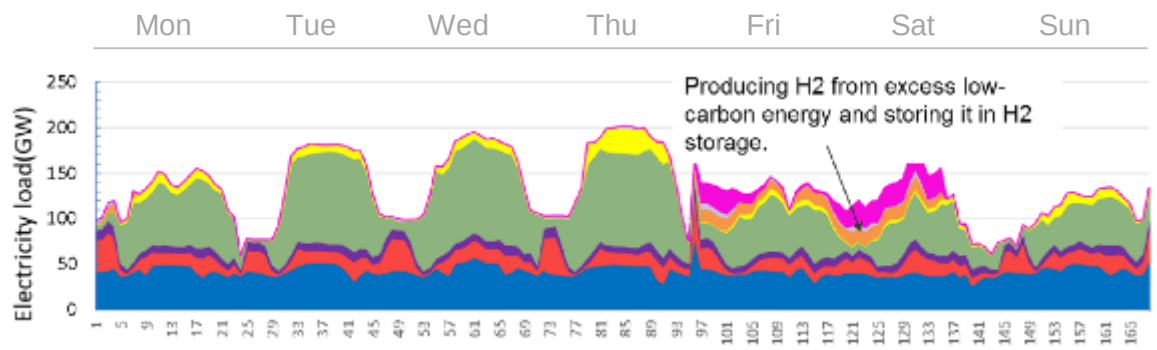
[1] Customers may choose to operate the hybrid system in such a way that maximises use of the heat pump (e.g., with pre-heating) and minimised use of the gas boiler; there is also a risk they will too frequently use the boiler (e.g., to heat faster when they haven't done sufficient pre-heating).
SOURCES: Imperial College of London for UK Committee on Climate Change(2018)

Solving for peak: in electrification with heat pumps pathway we require peaking plants (H_2 or CH_4) to serve the peak electricity demand, should renewable output be low during peak

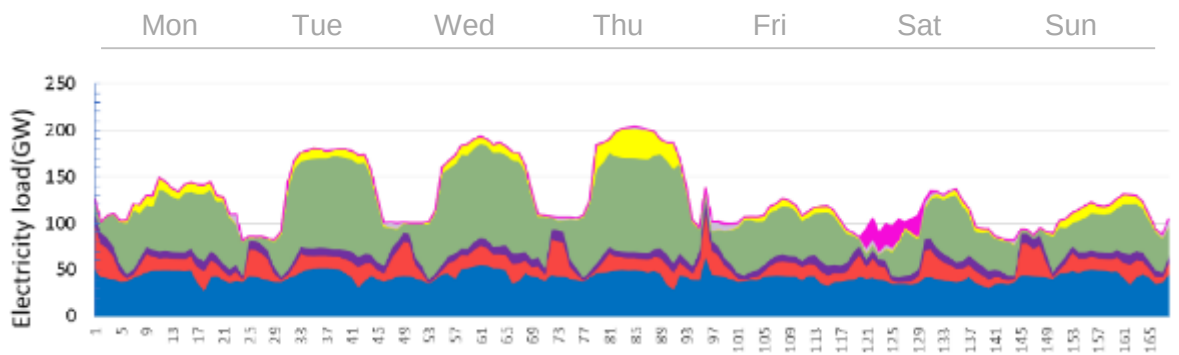
Under electrification scenarios in 2050, example electricity load & generation profiles over 1-week, wind not blowing for 3 days

GW

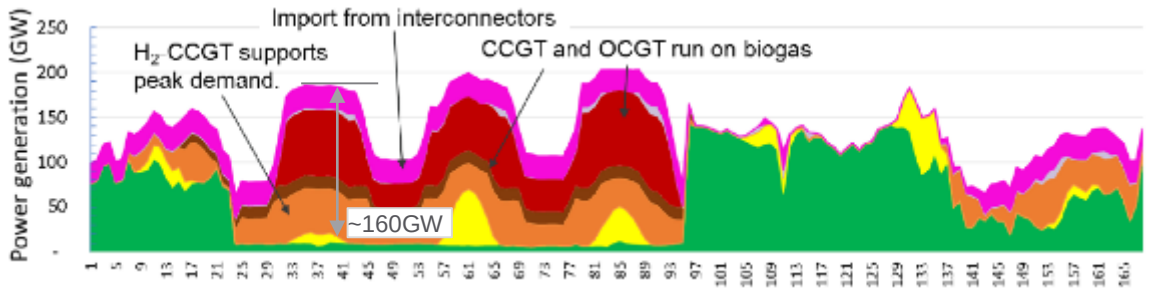
nuclear NOT part of the generation fleet, higher wind & solar

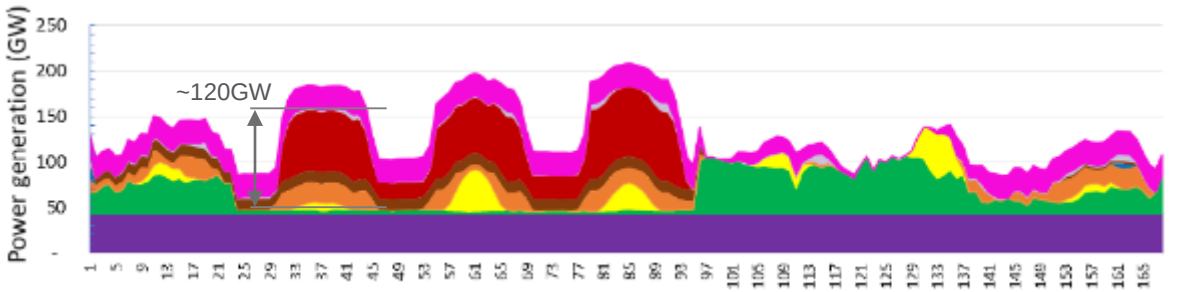


nuclear as part of the generation fleet



Key Baseload incl. I&C | EV | Smart Appliances | Heat Pumps | Resistive Heat | Power to Gas (H2) | Storage | Export

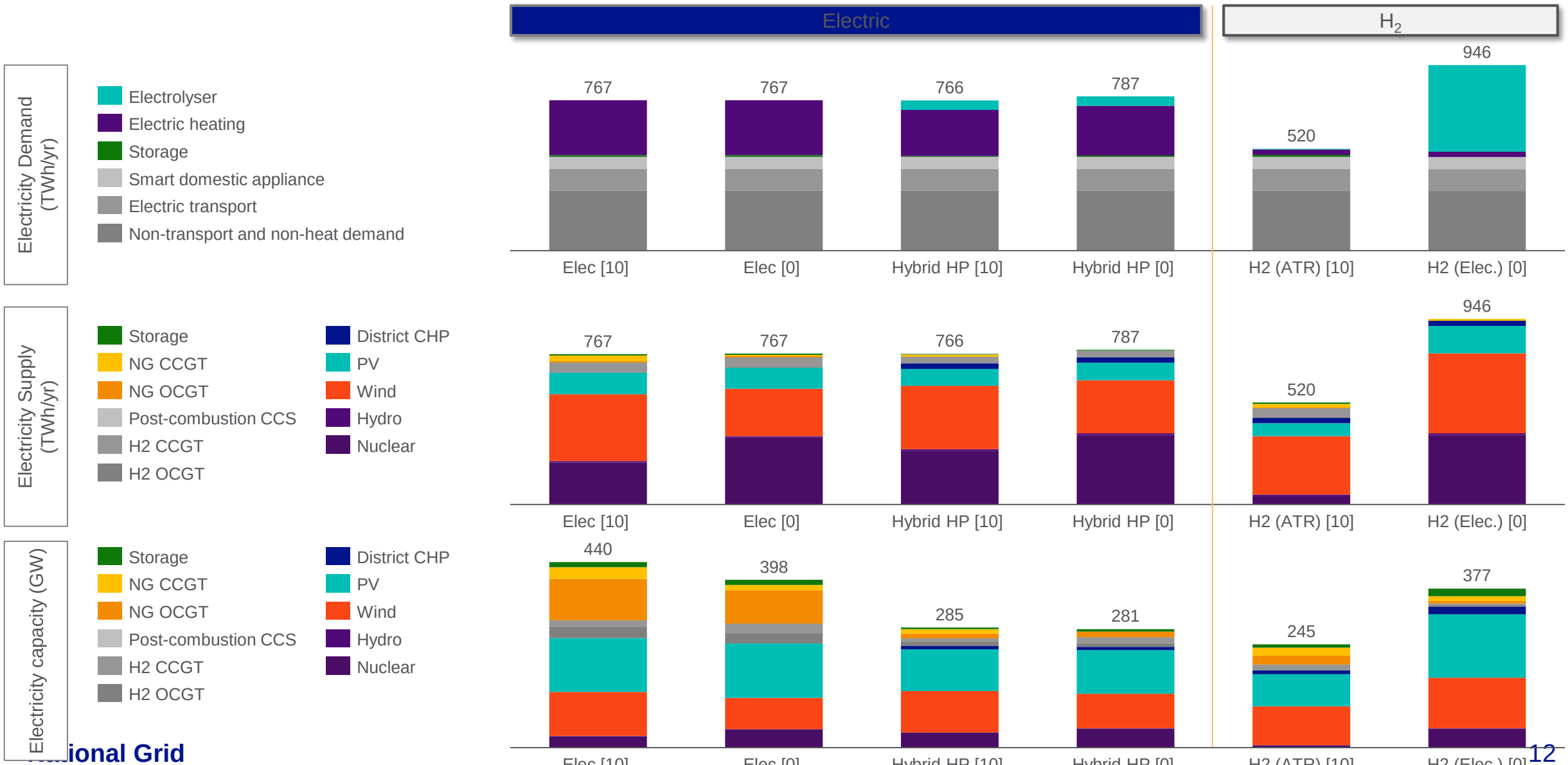




Key Nuclear | Wind | PV | H2 CCGT | H2 OCGT | CCGT | OCGT | Storage | Import | Other

SOURCES: Imperial College of London for UK Committee on Climate Change(2018)

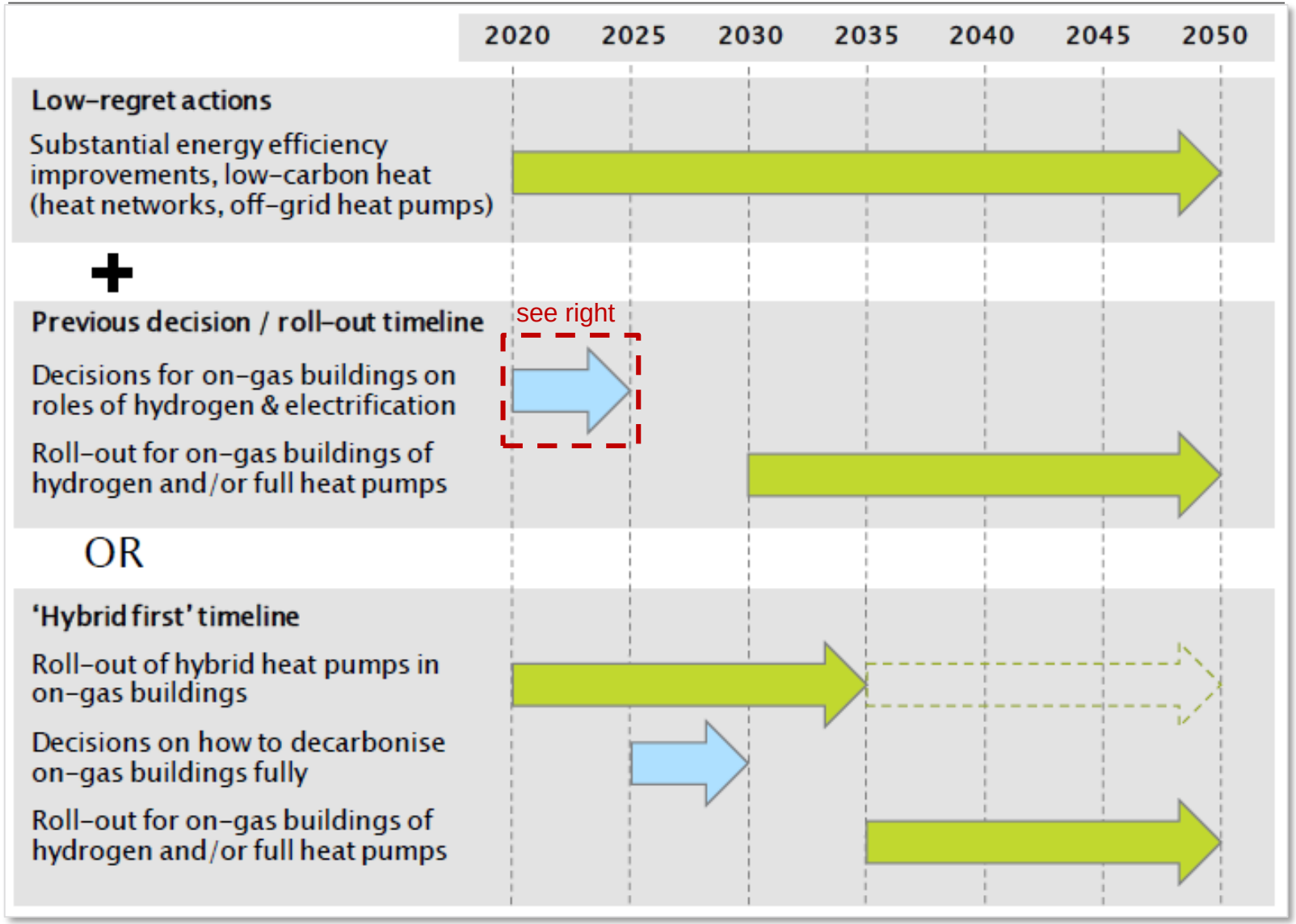
Solving for peak: in electrification with heat pumps pathway the peaking plants (H_2 or CH_4) see low utilisation



SOURCES: Imperial College of London for UK Committee on Climate Change(2018)

Path forward: 'no regrets' can be pushed; pilots / trials & further study required to close uncertainties; government decision to come in ~mid 2020s

Timing of key decisions and changes to deliver the net-zero scenarios for buildings



Near-term activities

- **Studies and demonstration projects to make the case for hydrogen**, e.g.:
  - BEIS reports on H_2 value chain, domestic conversion, etc.
  - Hy4Heat: proving building conversion (technical details, safety, convenience)
  - H21: quantified evidence for safe transport of H2 in gas distribution; technical design for converting north of England

  Gas distribution networks active
- **Reports, trials and innovation to push heat pumps and bioenergy**, e.g.:
  - BEIS reports: HP peak impact, bioenergy review, DSR in smart grids
  - BEIS Innovation: funds for heat pumps, hydrids, next gen HPs, microCHP & storage

SOURCES: UK Committee on Climate Change 'Net Zero' Technical report; "previous decision / roll-out timeline" reflects the UK CCC's 2016 recommendation

Imperial College for CCC (2018)

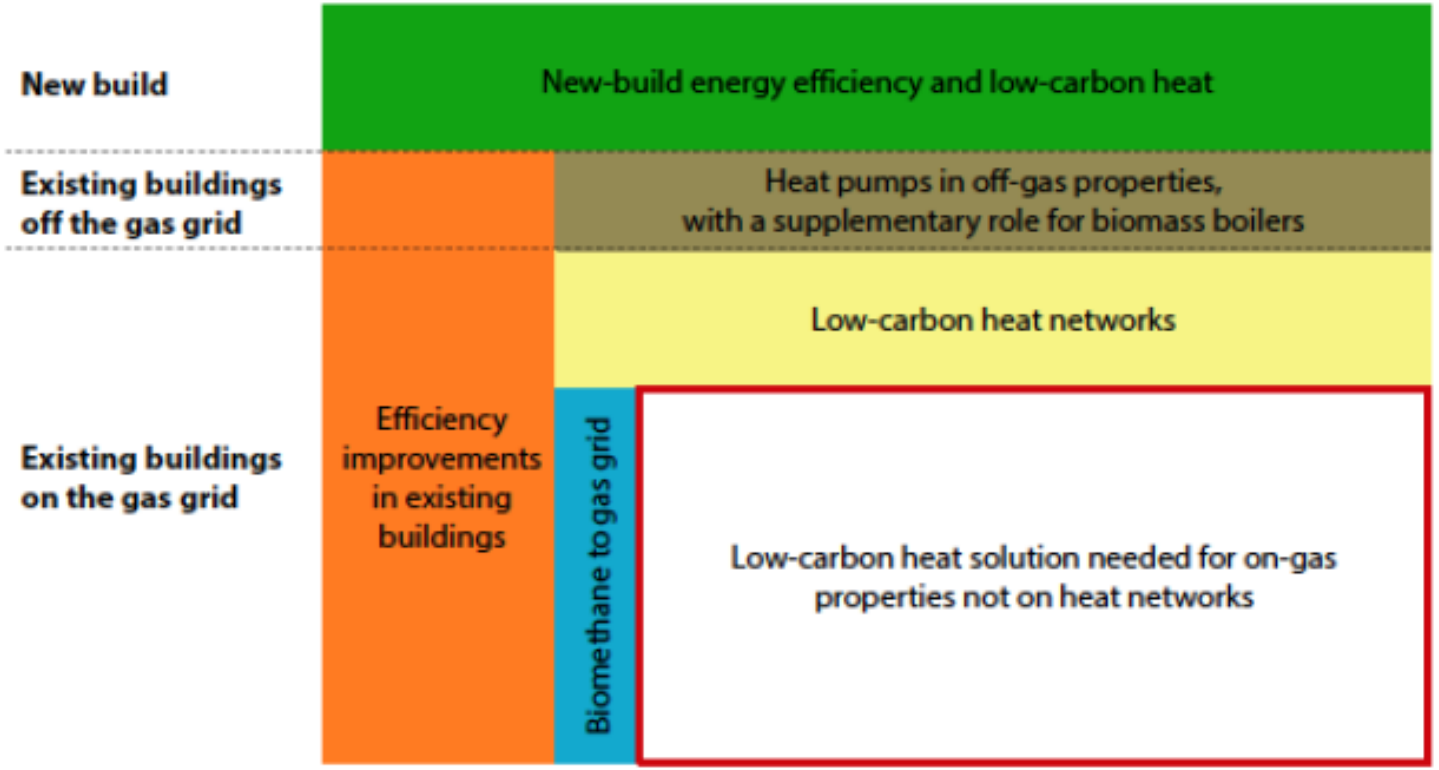


Figure E. 1 Low-regrets measures and the remaining challenge for existing buildings on the gas grid[7]

SOURCE: Imperial College of London for UK Committee on Climate Change(2018)

Imperial College for CCC (2018)

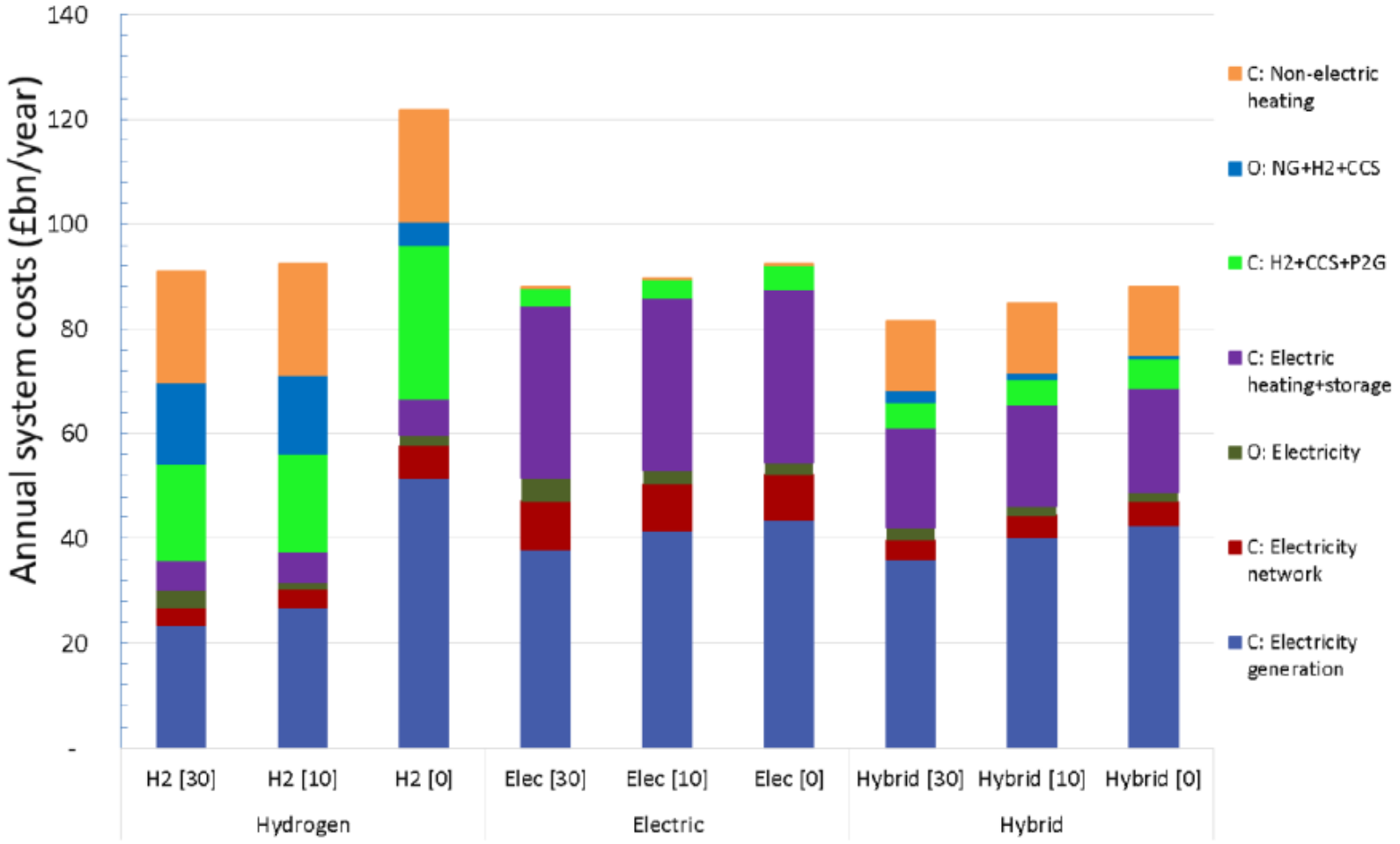
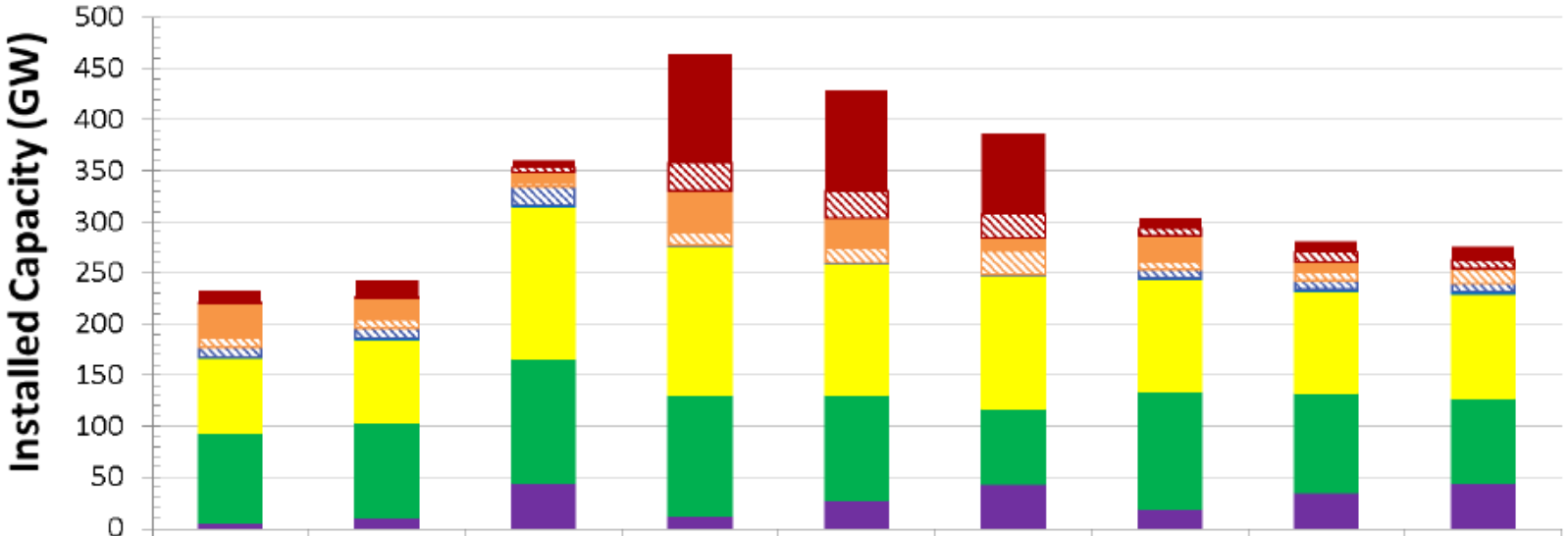


Figure E. 2 Annual system cost of core decarbonisation pathways

SOURCE: Imperial College of London for UK Committee on Climate Change(2018)

Imperial College for CCC (2018)



	H2 [30]	H2 [10]	H2 [0]	Elec [30]	Elec [10]	Elec [0]	Hybrid [30]	Hybrid [10]	Hybrid [0]
	Hydrogen			Electric			Hybrid		
OCGT	12	16	6	106	98	79	9	11	13
H2 OCGT	0	0	5	27	27	24	8	10	9
CCGT	35	21	11	41	28	13	26	11	0
H2 CCGT	9	9	3	12	15	23	7	8	14
District CHP	9	9	18	0	0	0	8	8	8
Hydro	1	1	1	1	1	1	1	1	1
PV	74	81	150	146	128	129	110	99	103
Wind	87	93	120	117	104	74	115	98	82
Nuclear	5	10	45	13	27	43	19	35	45

Figure E. 3 Optimal generation portfolio in the core decarbonisation pathways

SOURCE: Imperial College of London for UK Committee on Climate Change(2018)

Imperial College for CCC (2018)

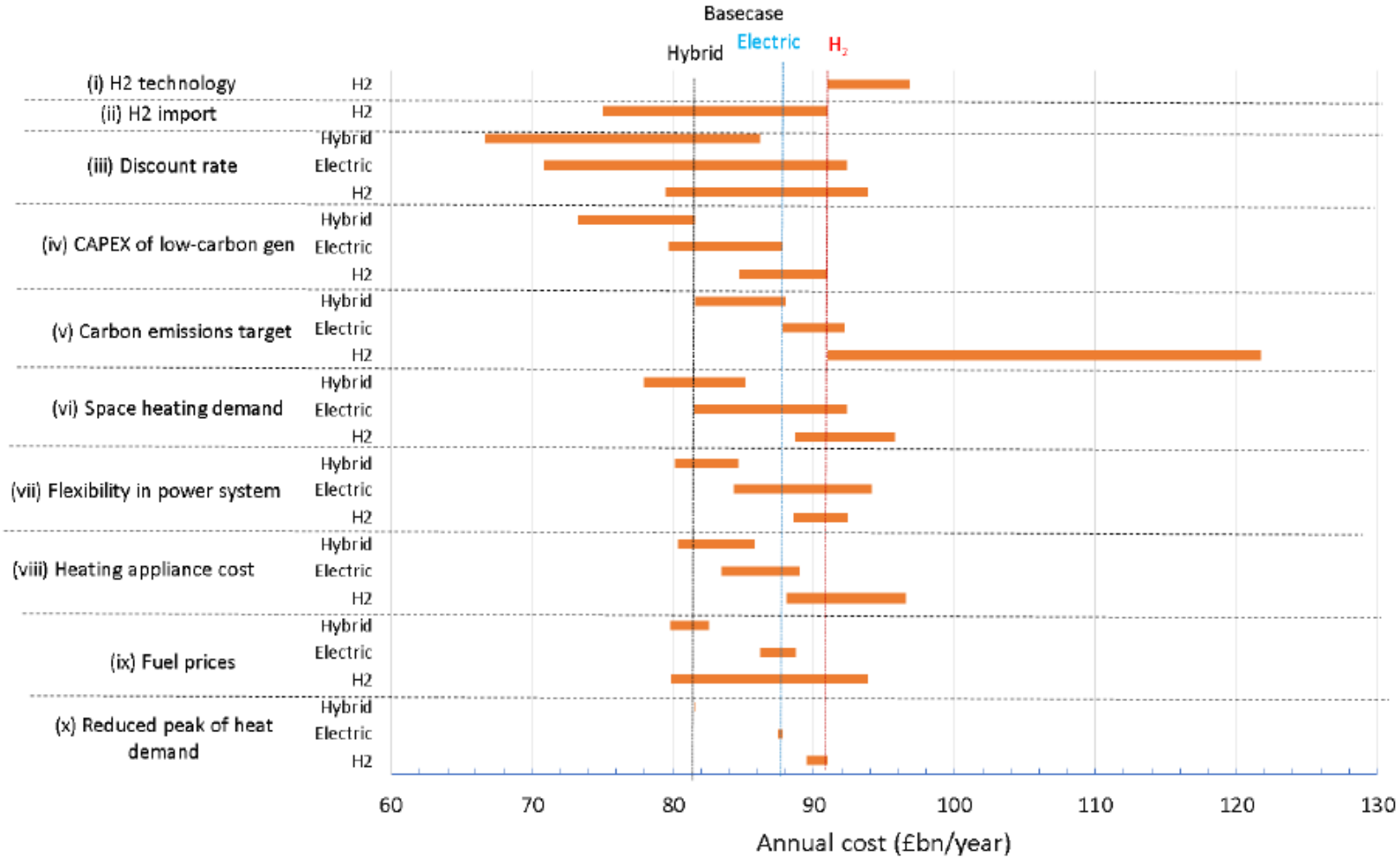


Figure E. 4 Cost changes in core decarbonisation pathways under different scenarios [30Mt]

SOURCE: Imperial College of London for UK Committee on Climate Change(2018)

Imperial College for CCC (2018)

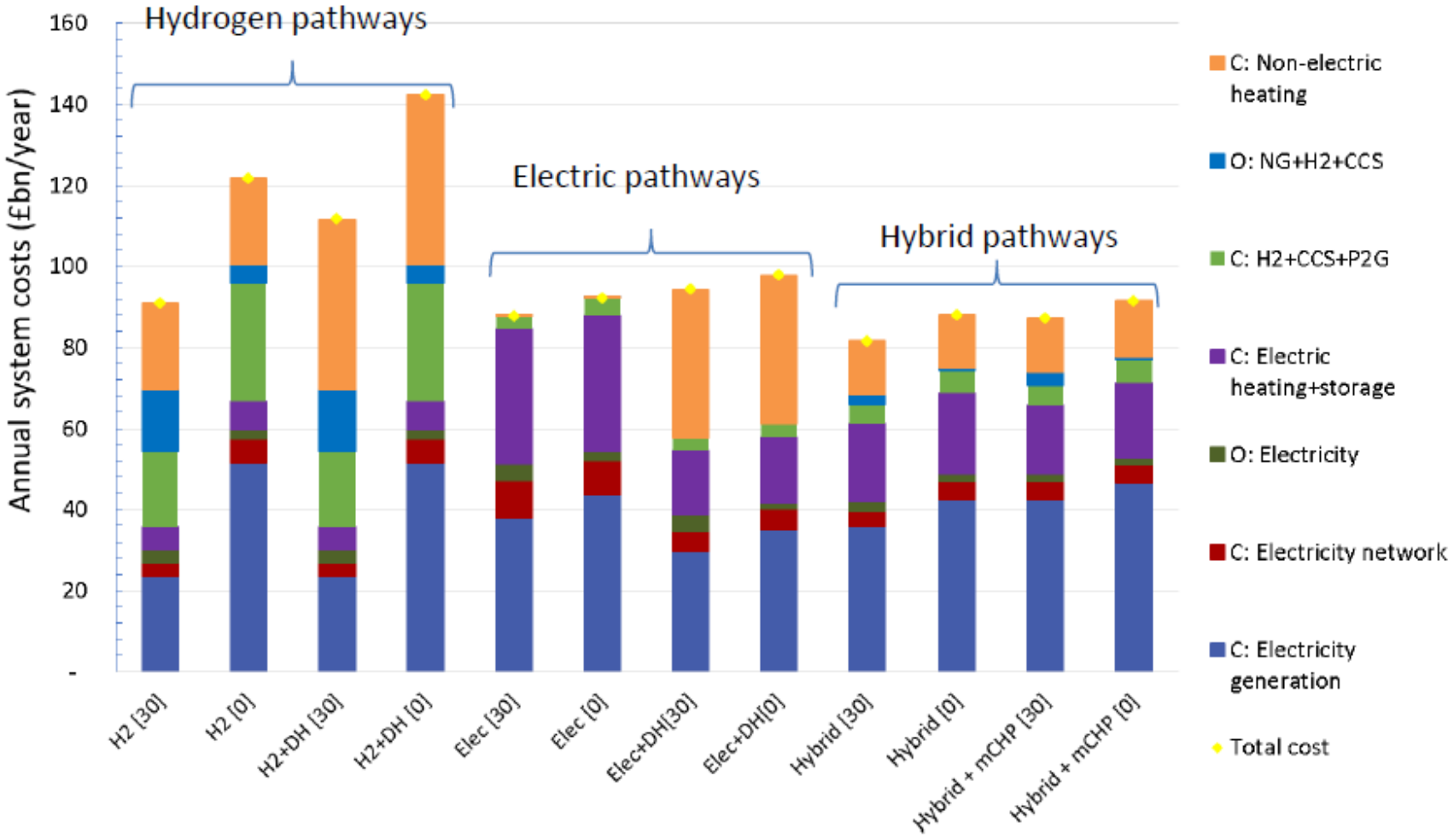


Figure E. 6 Annual system cost of different decarbonisation pathways

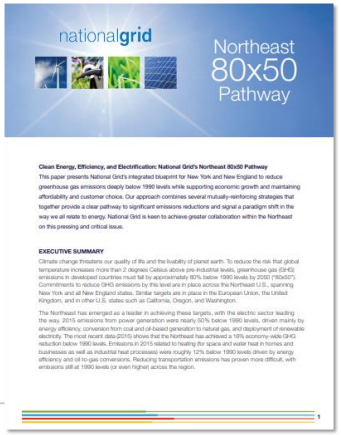
SOURCE: Imperial College of London for UK Committee on Climate Change(2018)

Toward a robust Northeast heat decarbonization strategy

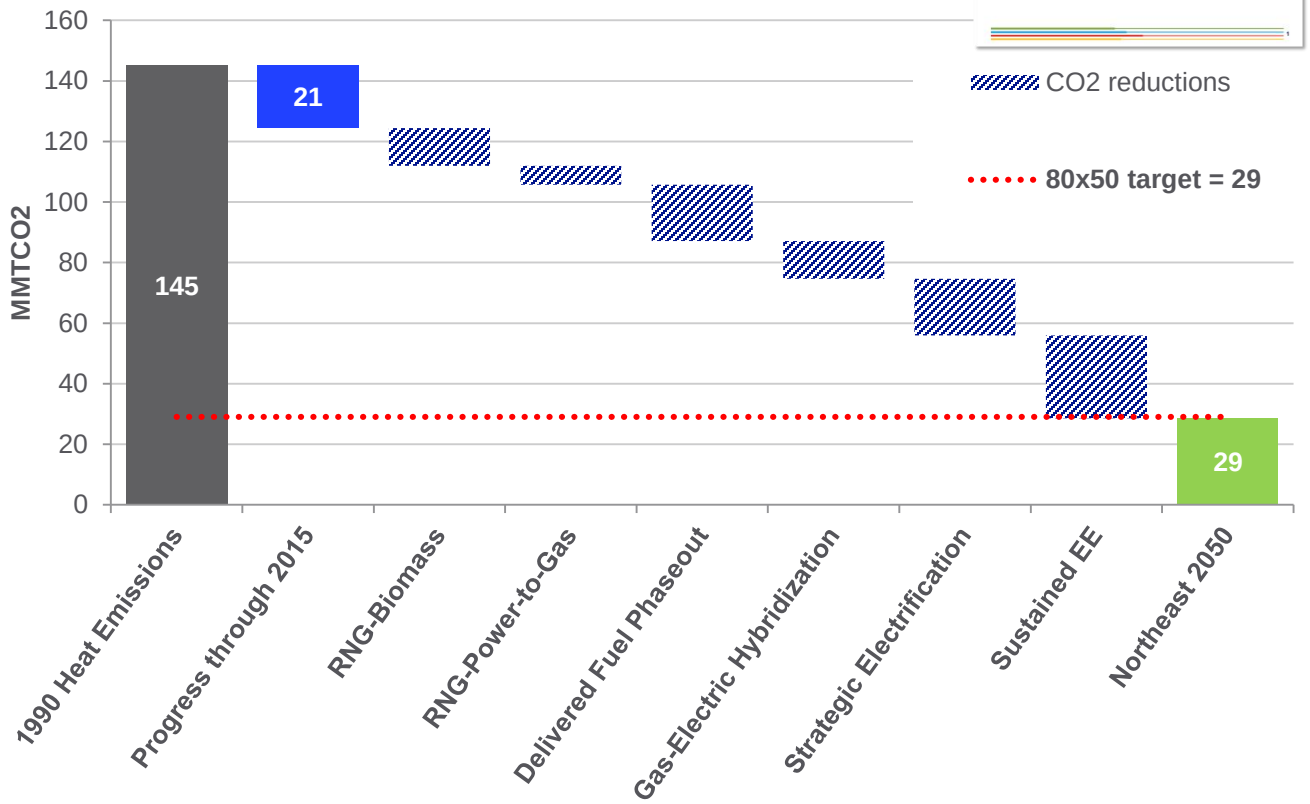
Heat pumps, hybrid homes, biomass, and hydrogen from electrolysis will all play a part.

Sustained building energy efficiency investment is foundational.

The Northeast decarbonization strategy will find a balanced mix of strategic electrification, decarbonized gas, and energy efficiency



Illustrative Pathway to Heat Decarbonization
(New York + New England)



The Role of Renewable Natural Gas

Significant activity around North America to decarbonize gas supply.

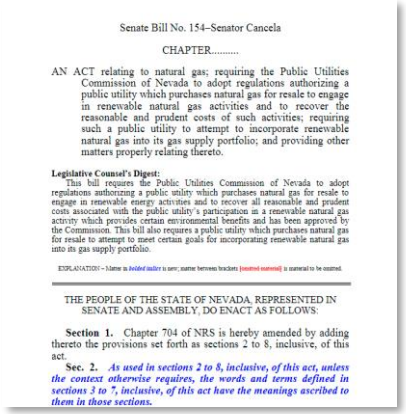
Utilities and third-party ecosystems are developing new business models.

Blend targets, carbon pricing and low-carbon fuel standards are a common denominator in major markets.

A robust policy foundation drives utility engagement and business model innovation

bp Clean Energy

2017: BP acquires Clean Energy Fuels for $155 million to become the prime national supplier of RNG.



Senate Bill No. 154–Senator Cancela

CHAPTER.....

AN ACT relating to natural gas; requiring the Public Utilities Commission of Nevada to adopt regulations authorizing a public utility which purchases natural gas for resale to engage in renewable natural gas activities and to recover the reasonable and prudent costs of such activities; requiring such a public utility to attempt to incorporate renewable natural gas into its gas supply portfolio; and providing other matters properly relating thereto.

Legislative Counsel's Digest:

This bill requires the Public Utilities Commission of Nevada to adopt regulations authorizing a public utility which purchases natural gas for resale to engage in renewable energy activities and to recover all reasonable and prudent costs associated with the public utility's participation in a renewable natural gas activity which provides certain environmental benefits and has been approved by the Commission. This bill also requires a public utility which purchases natural gas for resale to attempt to meet certain goals for incorporating renewable natural gas into its gas supply portfolio.

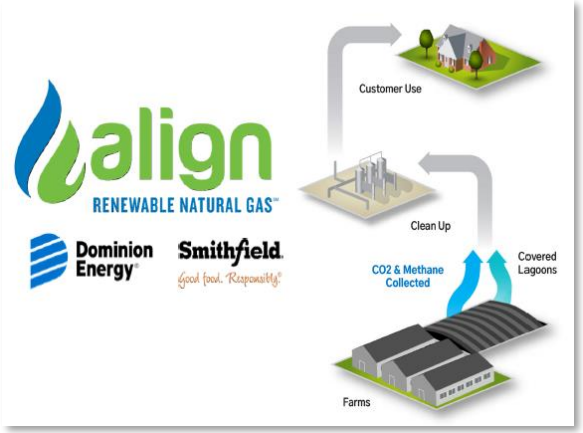
EXPLANATION – Matter in *bolded italics* is new; matter between brackets [omitted material] is material to be omitted.

THE PEOPLE OF THE STATE OF NEVADA, REPRESENTED IN SENATE AND ASSEMBLY, DO ENACT AS FOLLOWS:

Section 1. Chapter 704 of NRS is hereby amended by adding thereto the provisions set forth as sections 2 to 8, inclusive, of this act.

Sec. 2. *As used in sections 2 to 8, inclusive, of this act, unless the context otherwise requires, the words and terms defined in sections 3 to *, inclusive, of this act have the meanings ascribed to them in those sections.*

2018-19: RNG targets established or proposed in CA, NV, OR, CT



2019: $250 million JV launched between Dominion and Smithfield food – the largest RNG partnership in history.

Conclusion: Focusing on What Matters in Heat Decarbonization

Technical: Ensuring reliability at each home and across the system

Social: Equity and affordability to ensure political support

Financial: Understanding public policy costs and integrating with carbon pricing

Innovation: Unique opportunity for Northeast to ‘stand out’ in the innovation landscape

Policy: Meaningful (i.e. larger than rooftop PV) incentives will be required across a variety of sectors

Regulation: Performance-based regulation should be leveraged to incentivize utilities to pursue decarbonization

Leveraging our leadership nationally: How can the Northeast region propel national action well before 2030?