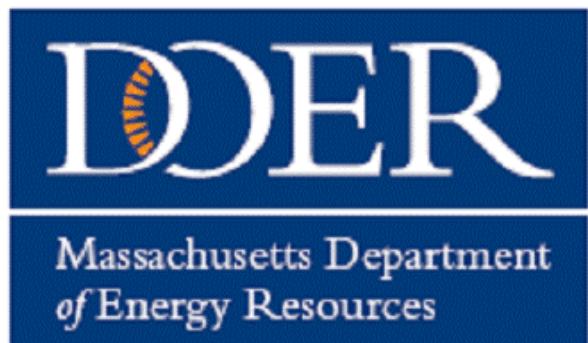
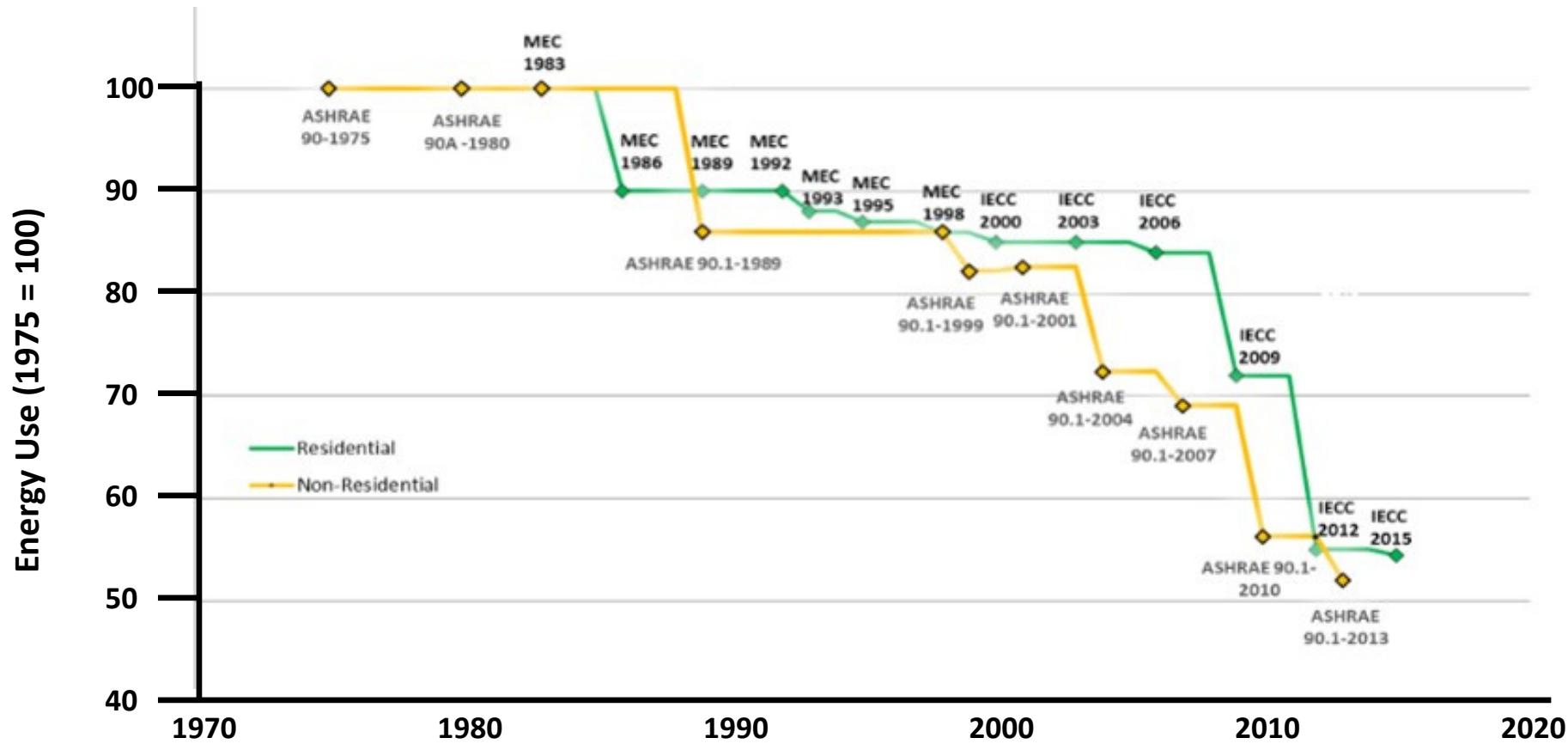
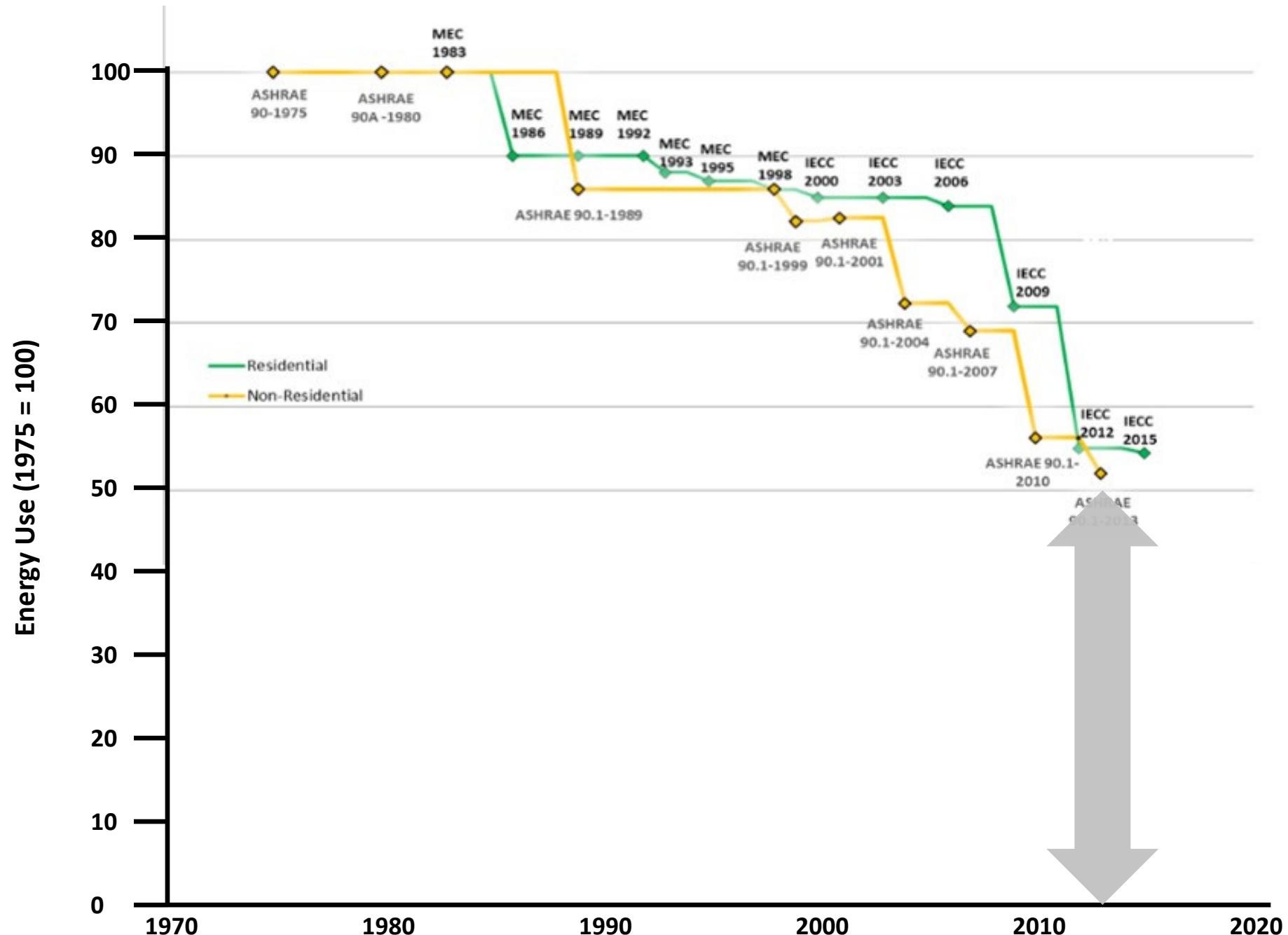


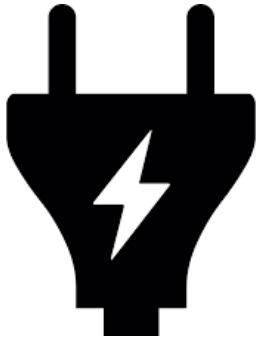
THE RACE TOWARDS CARBON NEUTRALITY: DRIVERS AND BARRIERS

March 14, 2019









electric energy

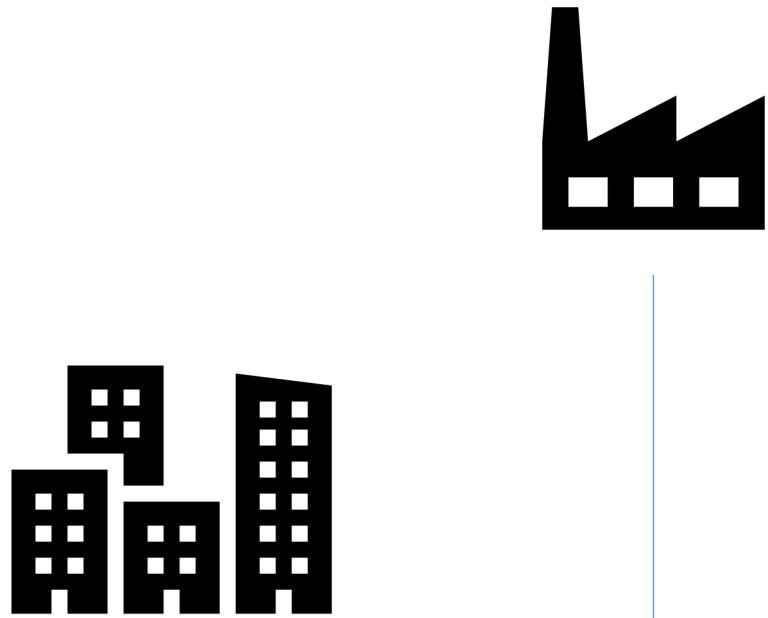
=



gas energy

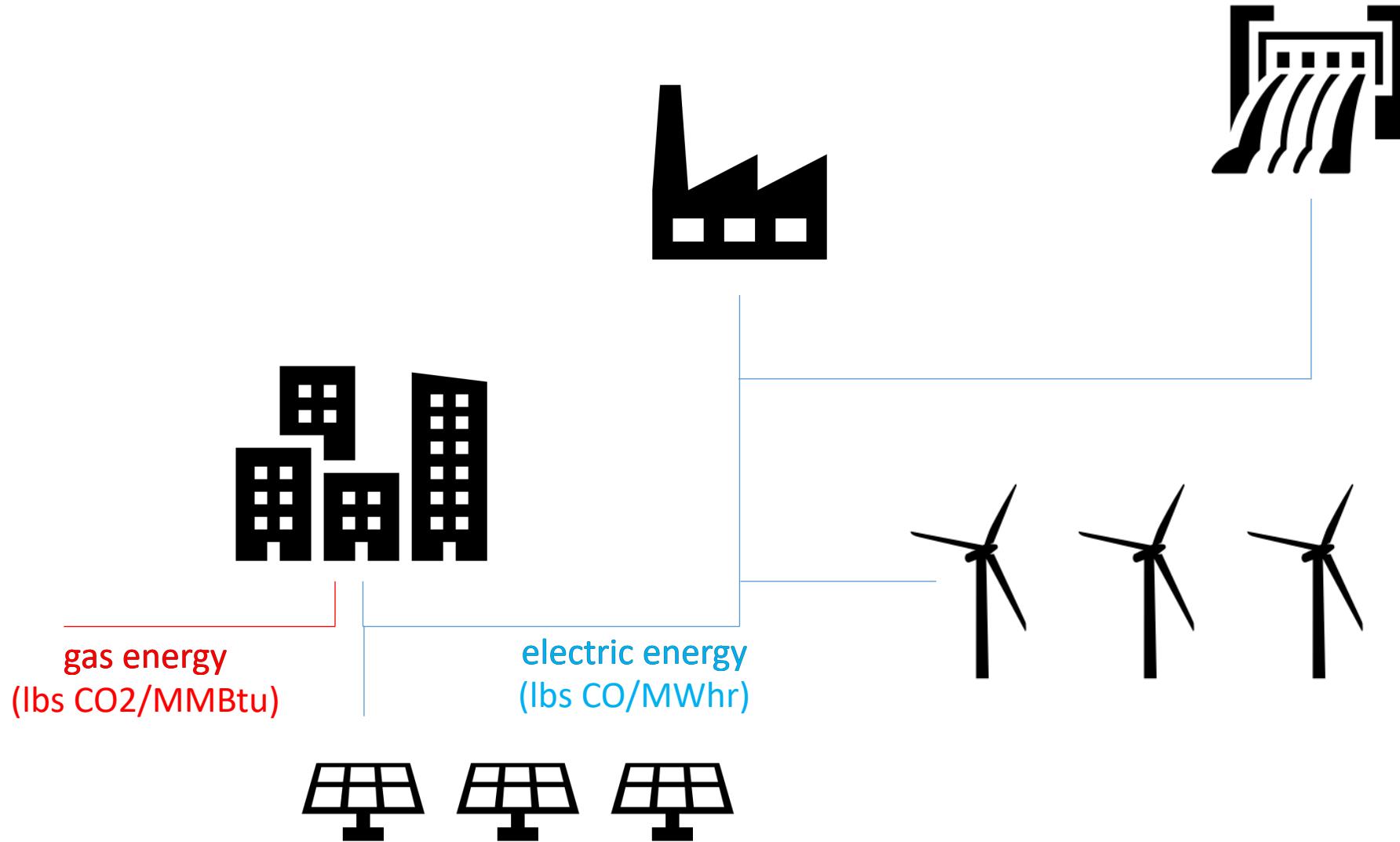
Last 50 years of Code:

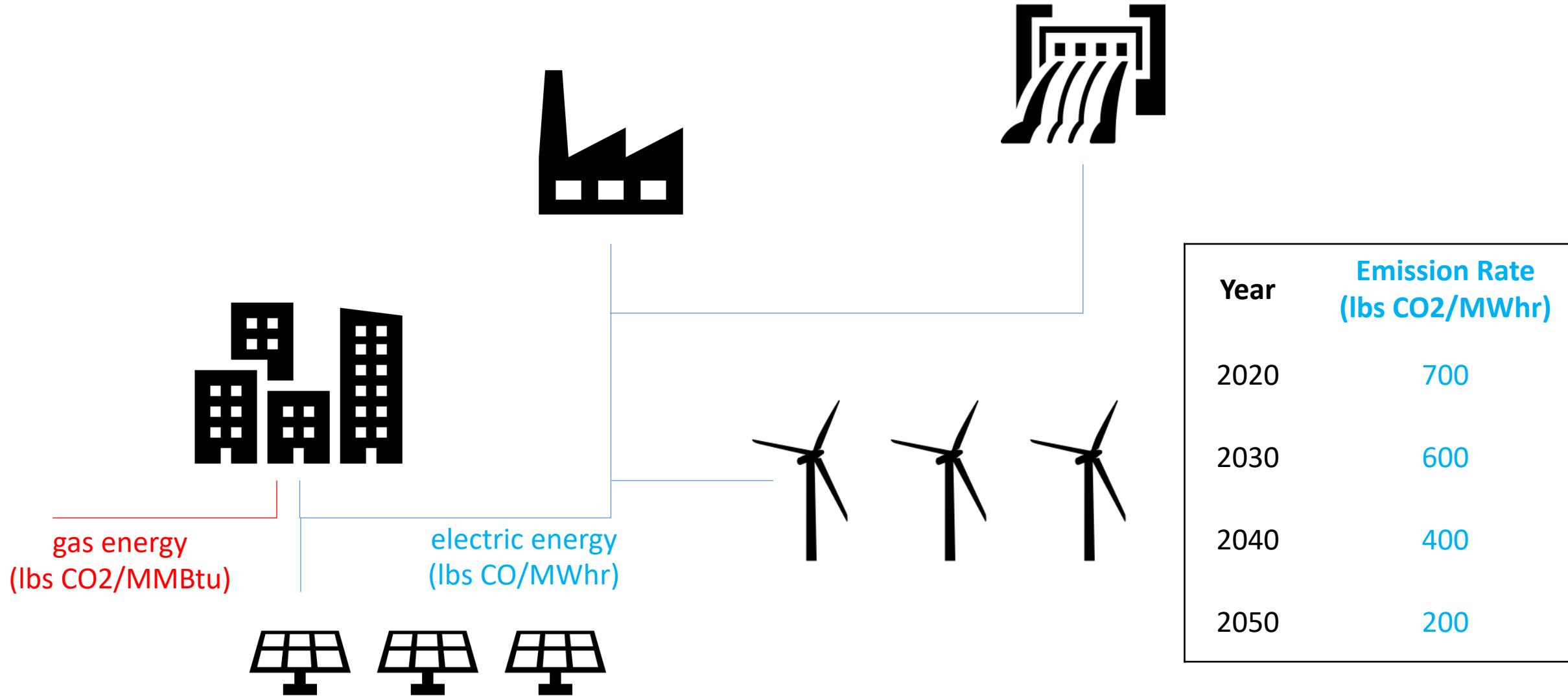
all saved energy (saved BTUs)
are the same



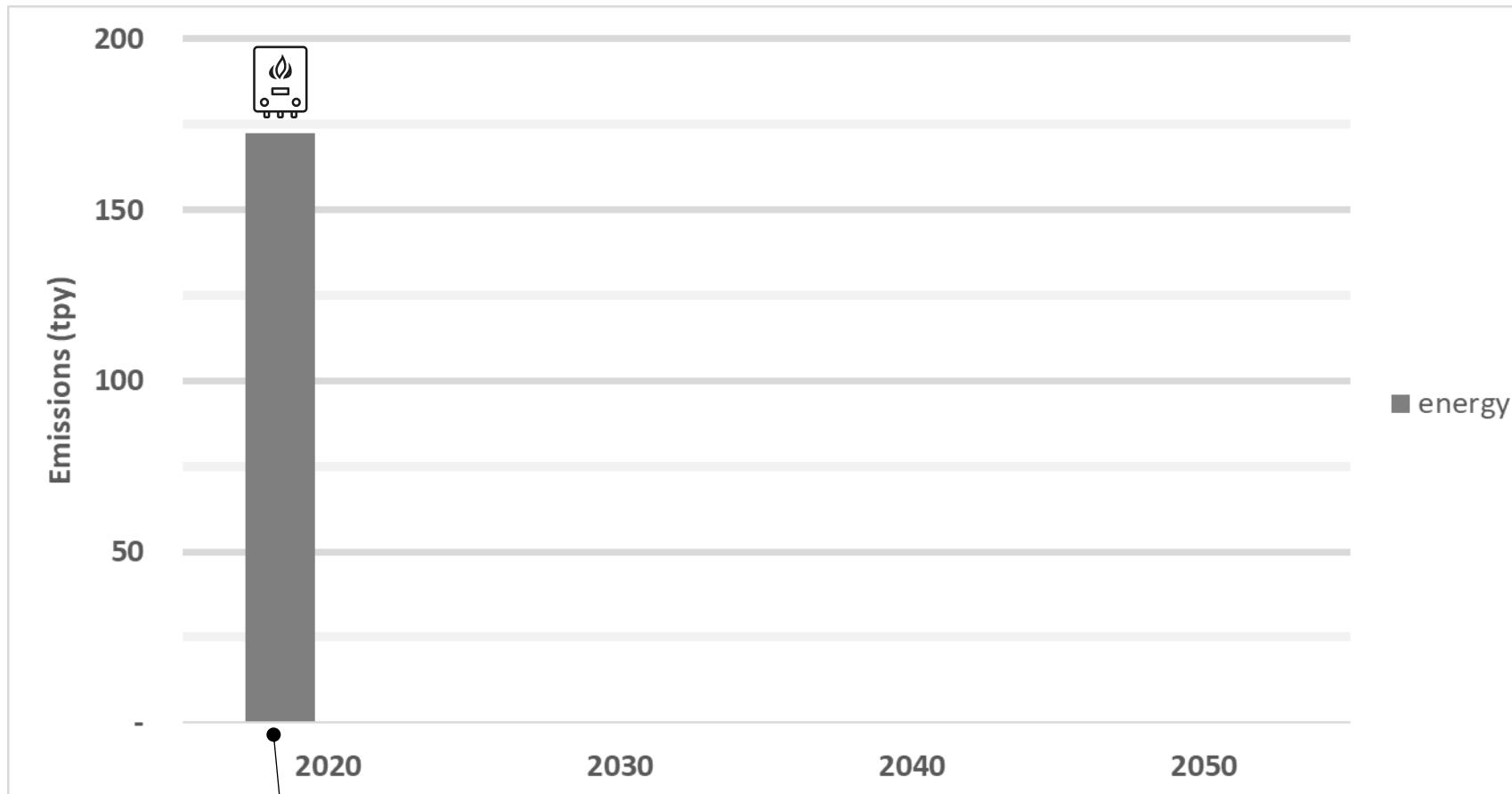
gas energy
(lbs CO₂/MMBtu)

electric energy
(lbs CO₂/MWhr)





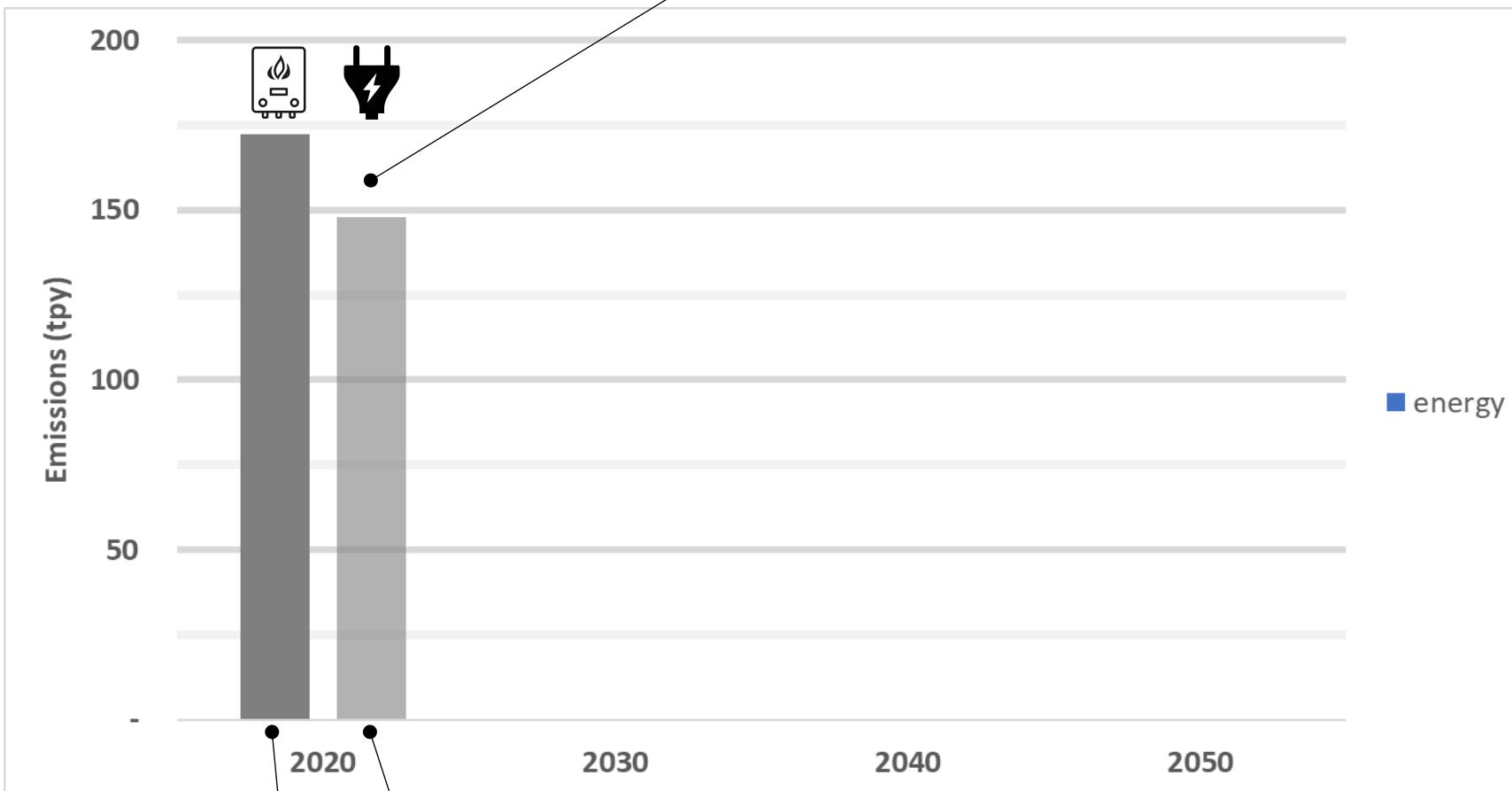
50,000-sf multifamily



Typically better-than-Code
building with **gas heat and**
hot water

50,000-sf multifamily

14% improvement

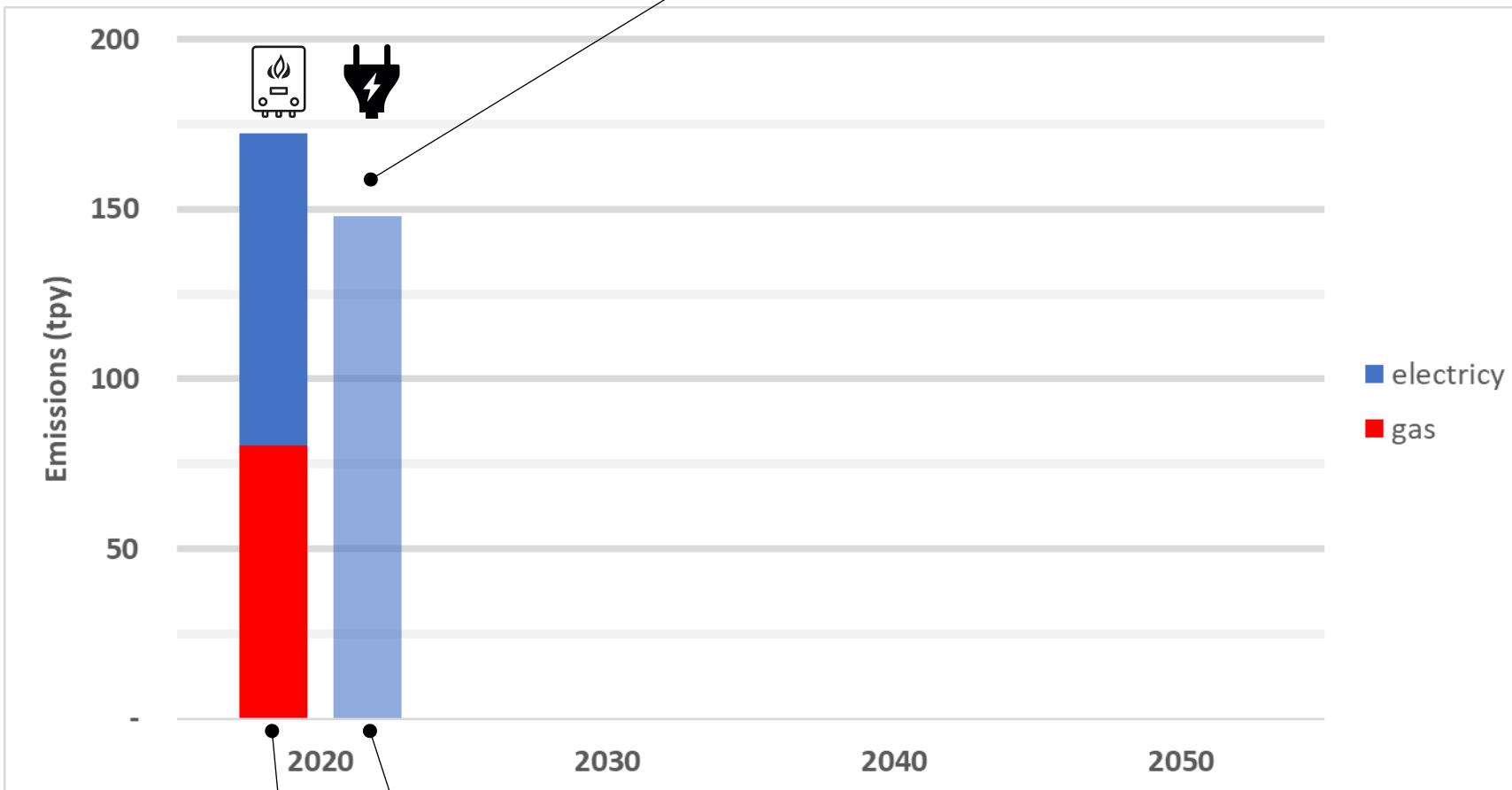


Typical better-than-Code building with **gas heat and hot water**

Swapping gas heat and hot water with **electric heat pump heat and hot water**

50,000-sf multifamily

14% improvement

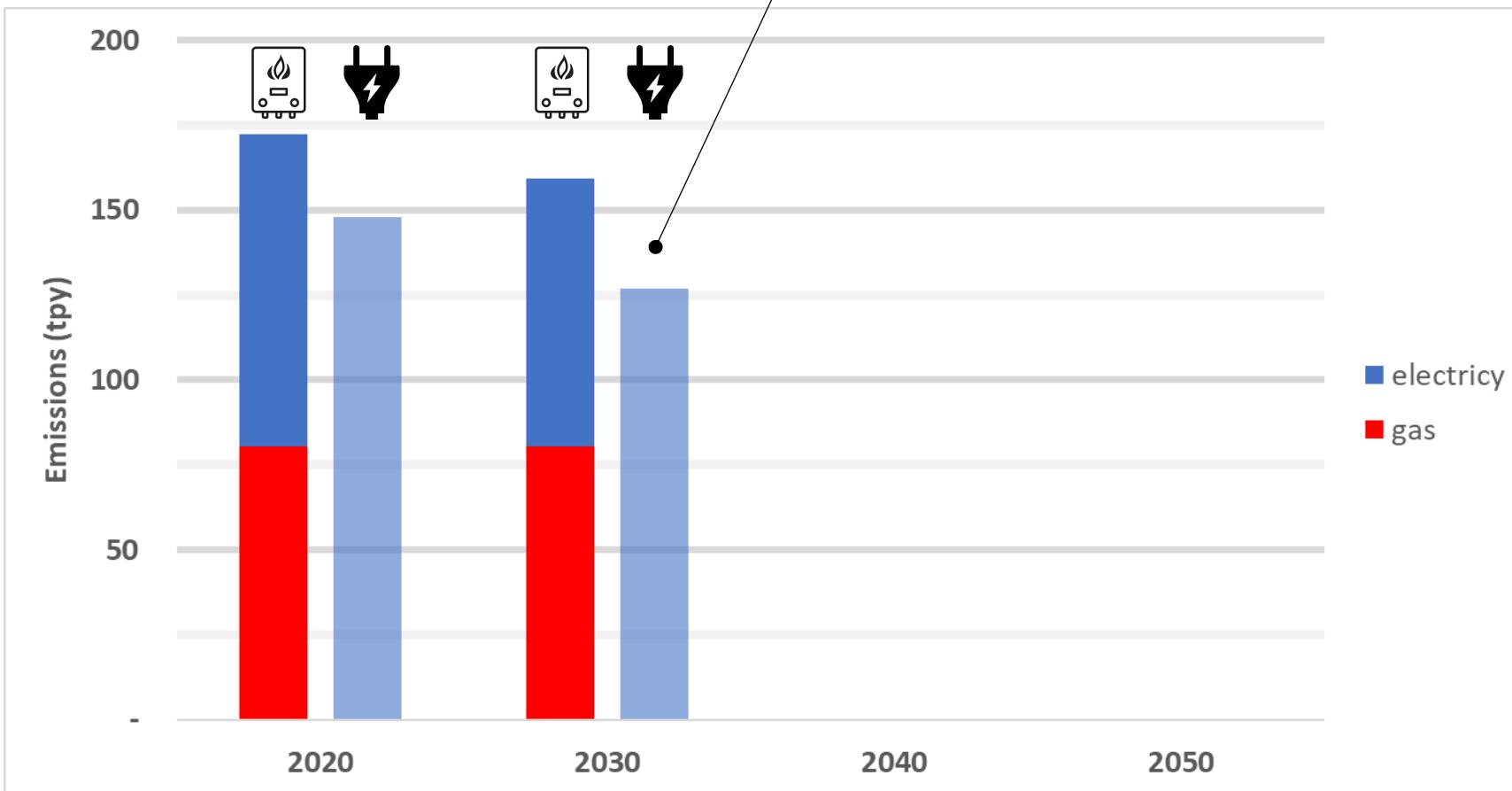


Typical better-than-Code
building with **gas heat and
hot water**

Swapping gas heat and hot
water with **electric heat
pump heat and hot water**

50,000-sf multifamily

20% improvement



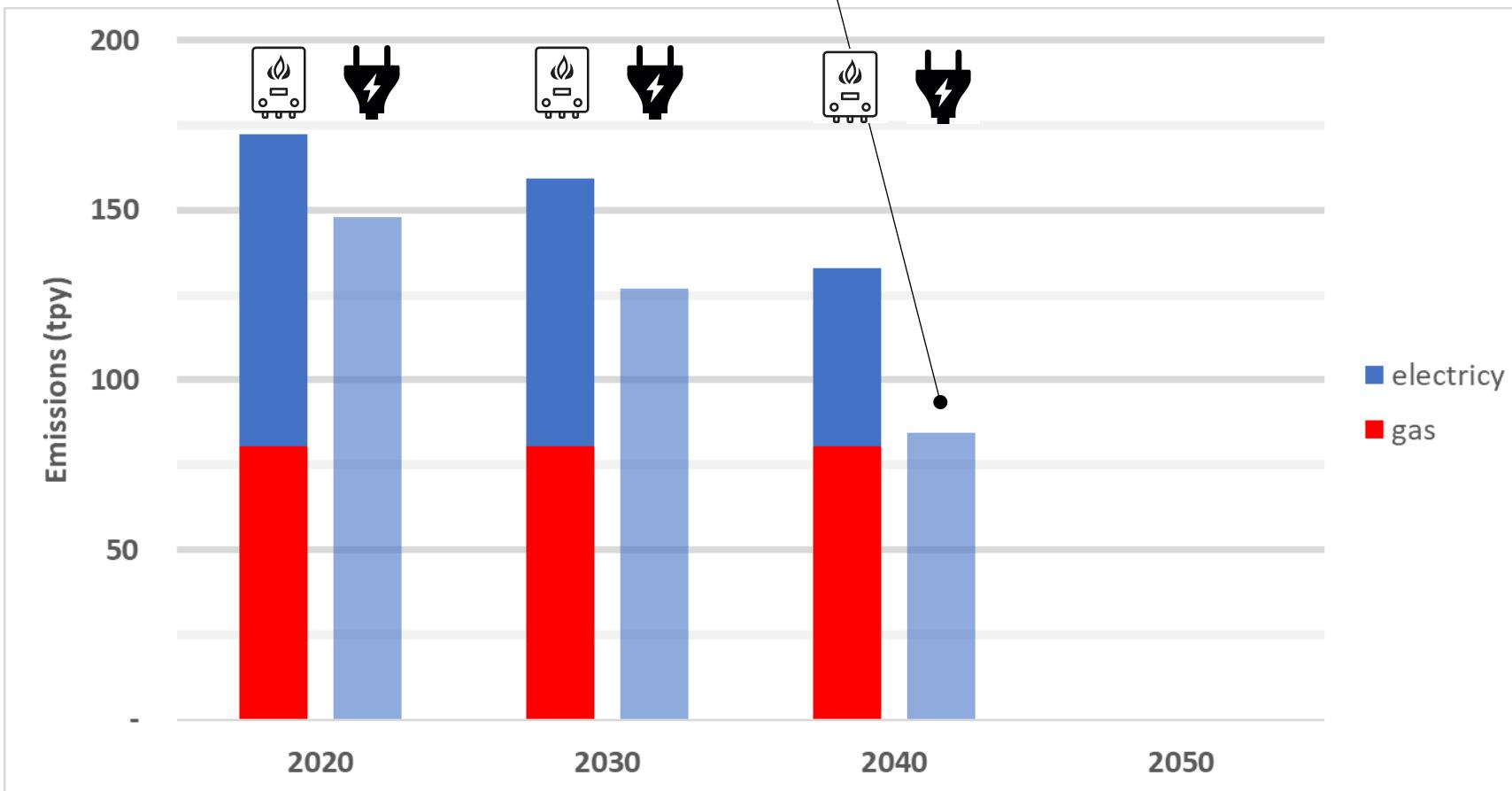
Electric Emission Rate
(Lbs CO₂/ Mwhr)

700

600

50,000-sf multifamily

36% improvement



Electric Emission Rate
(Lbs CO₂/ Mwhr)

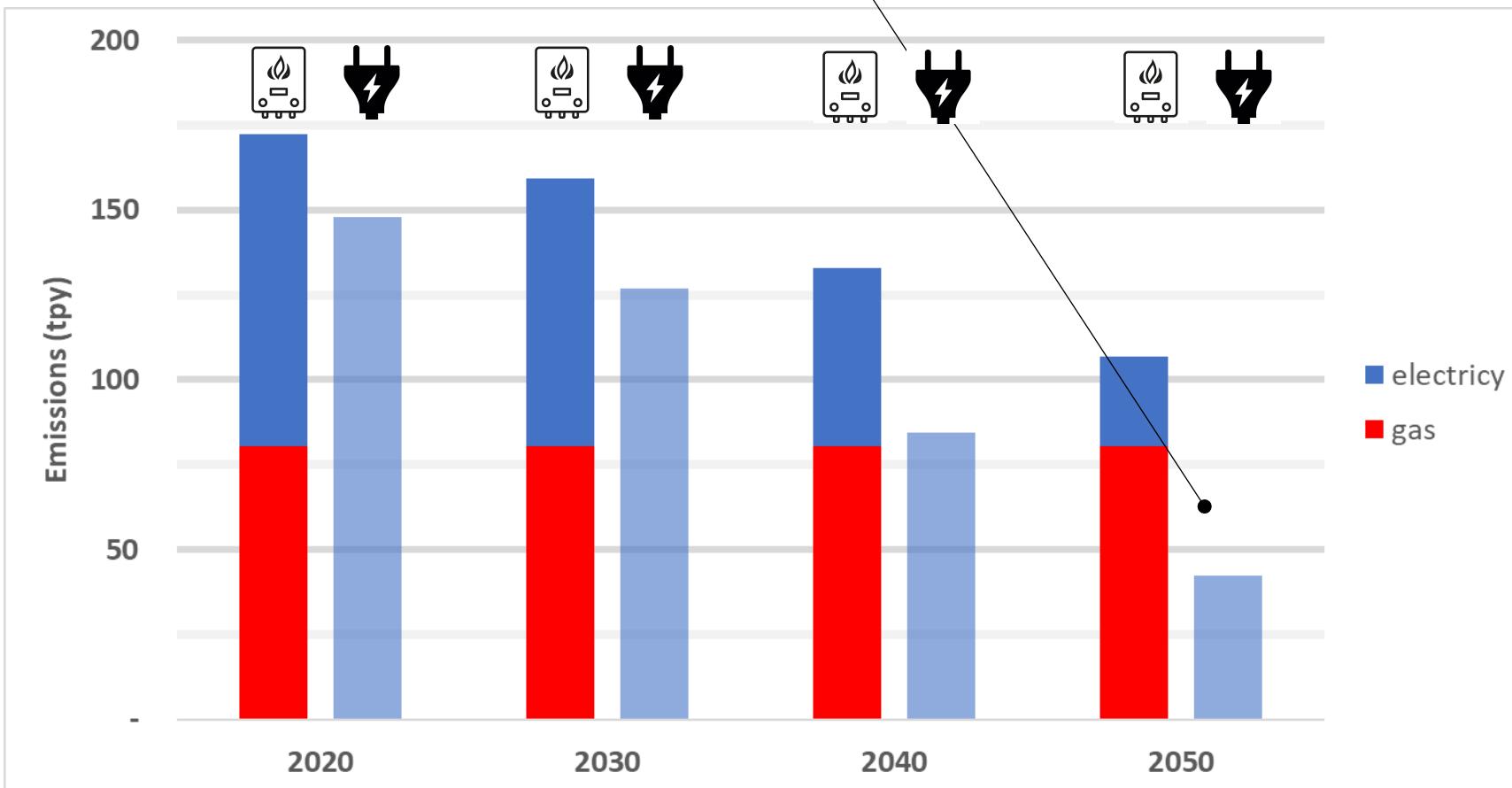
700

600

400

50,000-sf multifamily

60% improvement



Electric Emission Rate
(Lbs CO₂/ Mwhr)

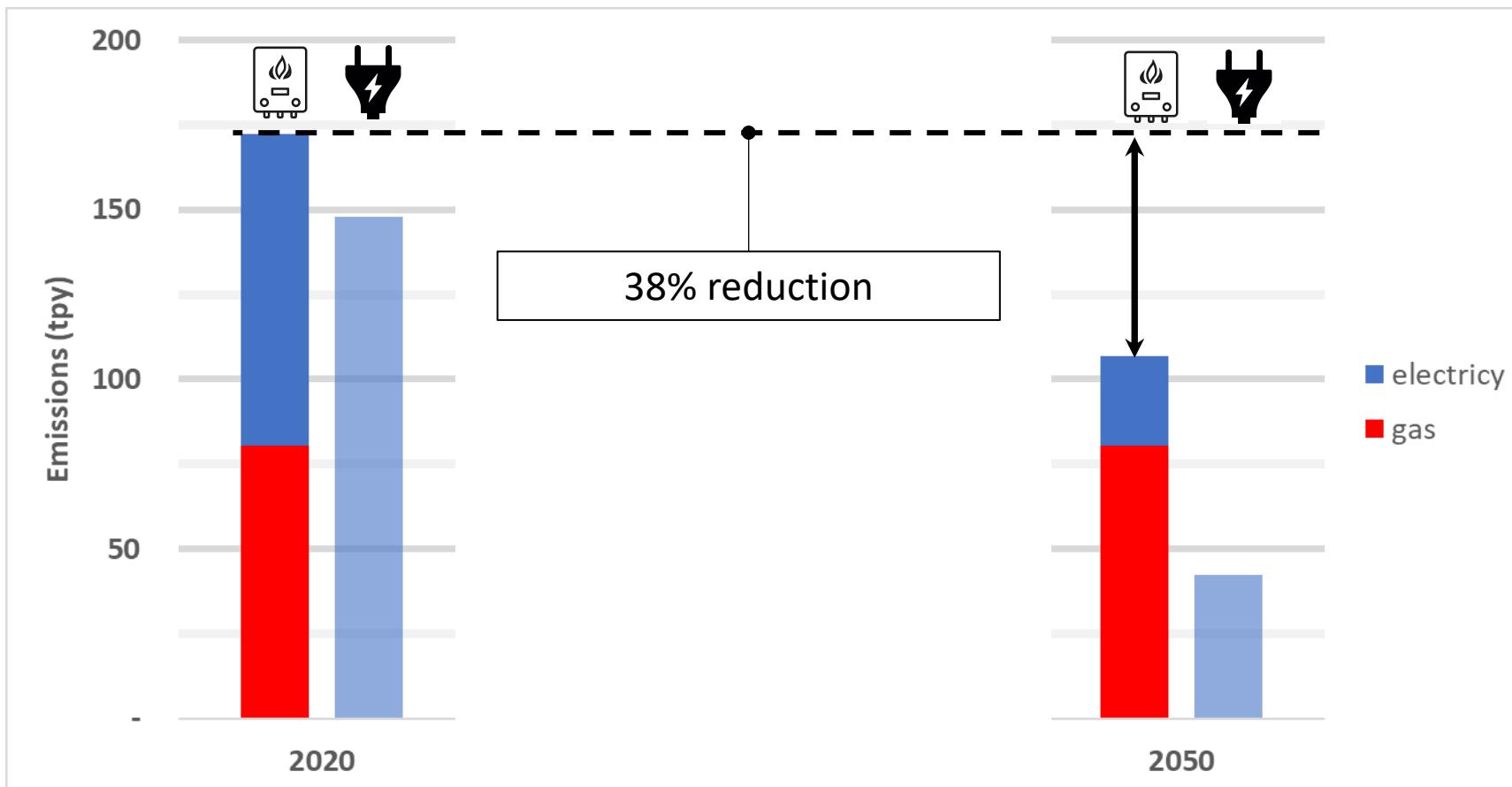
700

600

400

200

50,000-sf multifamily



**Electric Emission Rate
(Lbs CO₂/ Mwhr)**

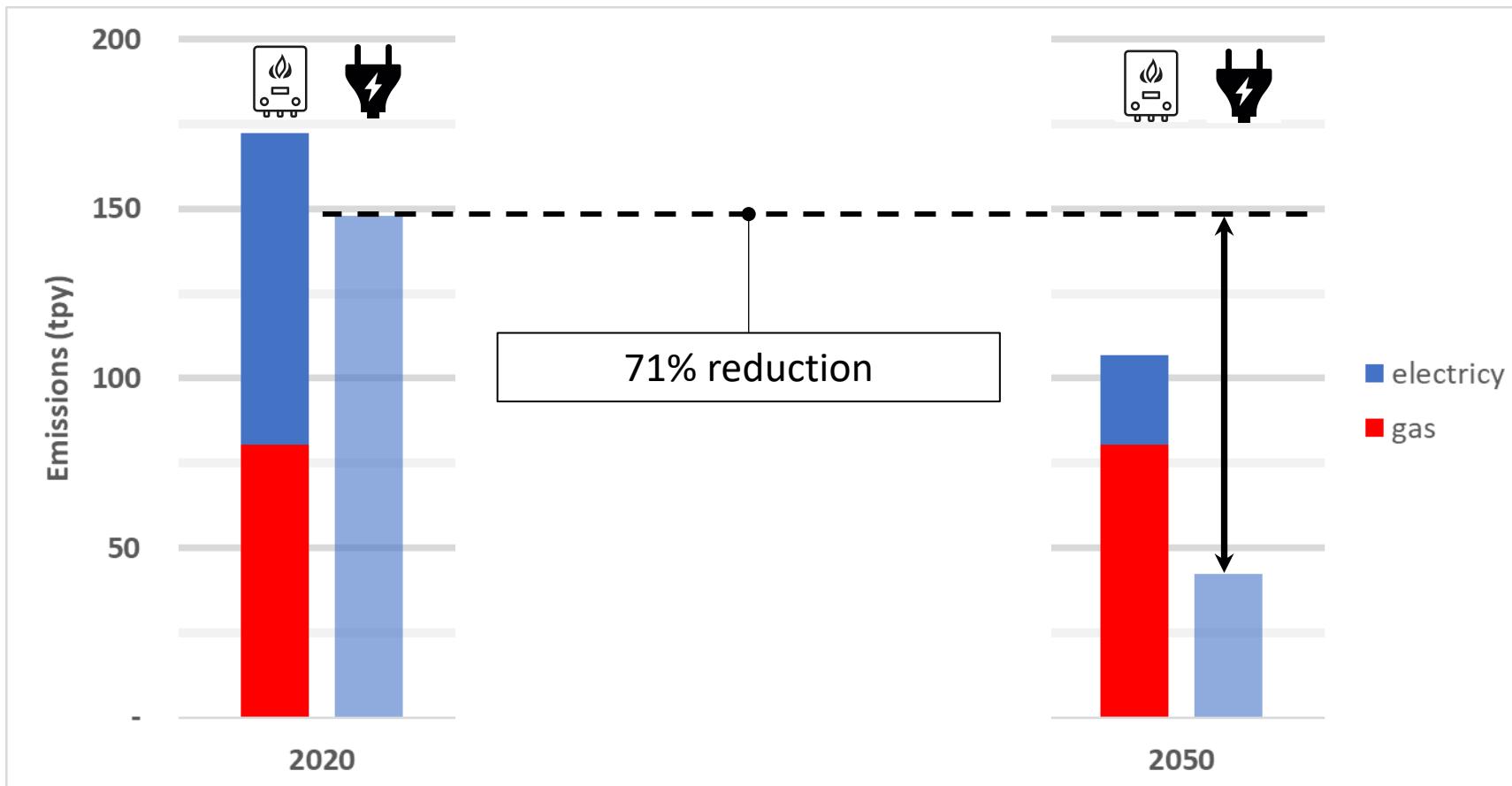
700

600

400

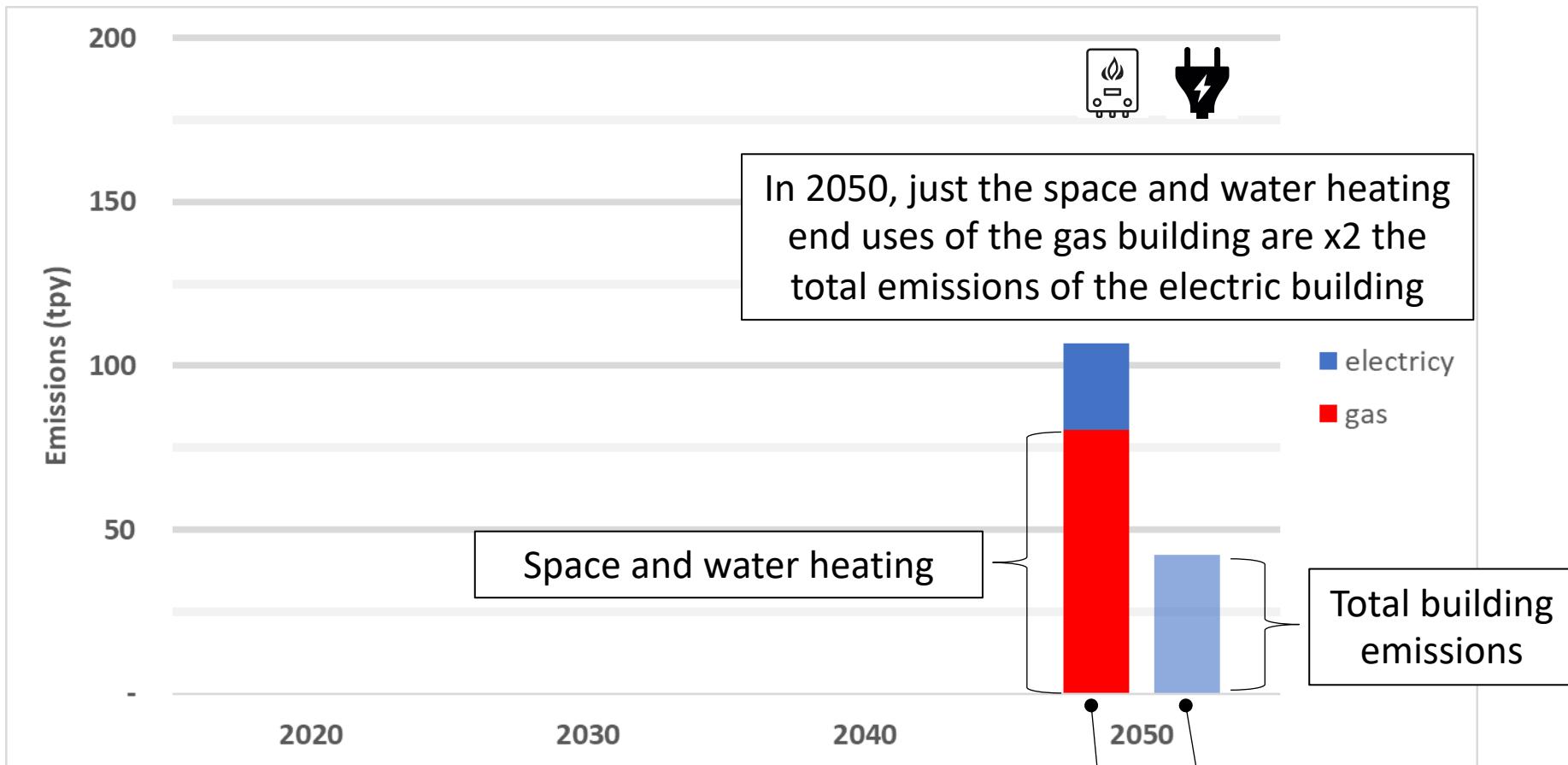
200

50,000-sf multifamily



Electric Emission Rate
(Lbs CO₂/ Mwhr)

50,000-sf multifamily



50,000-sf multifamily

\$1/therm
\$0.20/kWhr

Annual Cost	 Space heating and hot water with Gas	 Space heating and hot water with electric heat pumps
Gas	\$14,000	\$0
Electricity	\$52,000	\$85,000
Total	\$66,000	\$85,000

least cost

50,000-sf multifamily

\$1.50/therm
\$0.20/kWhr

Annual Cost	 Space heating and hot water with Gas	 Space heating and hot water with electric heat pumps
Gas	\$21,000	\$0
Electricity	\$52,000	\$85,000
Total	\$73,000	\$85,000

least cost

50,000-sf multifamily

\$1.50/therm
\$0.20/kWhr

Peak space heating:
12.4 btu/hr-sf

Peak space heating:
4.4 btu/hr-sf

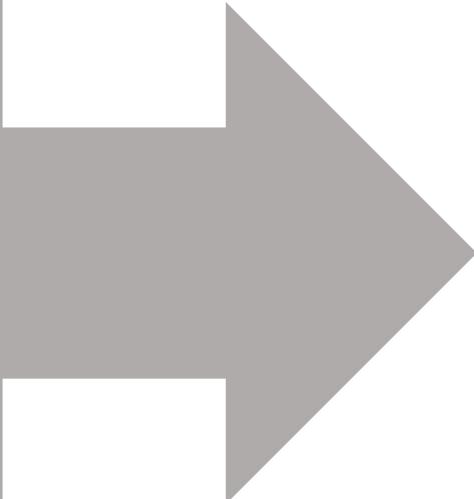
Annual Cost	Space heating and hot water with Gas	Space heating and hot water with electric heat pumps
Gas	\$21,000	\$0
Electricity	\$52,000	\$85,000
Total	\$73,000	\$85,000

+ PH Space heating and hot water with electric heat pumps and Passivehouse
\$0
\$64,000
\$64,000

least cost

ENABLING STEPS

- Envelope
- Air tightness
- *Peak heat limit?*
- *Total heat limit?*



**ELECTRIFICATION
OF HEATING**

Idea

Implementation into Code

Not all Btus are the same

- Emissions basis, not Btu basis
- Recognize future grid emission rates

Electrify space and water heating

- Heat pump space heating
- Heat pump water heating
- Heating peak limits (btu/sf-hr); total heat limits (btu/sf-yr)
- Envelope backstop

Enabling Steps to Electrify