The Economic Impact of Expanding Natural Gas Use in Connecticut

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Executive Summary

Southern Connecticut Gas, Connecticut Natural Gas and Yankee Gas commissioned the Department of Economic and Community Development (DECD) to perform an economic analysis of a gas main expansion scenario leading to increased customer conversions from oil heat to natural gas heat. The buildout and conversion period occurs between 2012 and 2021 during which there is significant construction and changeover from oil to natural gas space and water heating equipment that drives new economic activity.

The expansion of Connecticut's natural gas infrastructure entails costs and benefits for home and business owners. The costs include both the customer costs to convert hearing equipment and the utility's costs to expand mains and connect homes and businesses to the system including service and meter costs. The benefits include increased economic activity due to increased construction activity, reduced customer bills due to the price differential between oil and gas. In addition, the analysis includes the loss of oil heating business as a cost and the reduction of CO_2 emission and its related price as a benefit. The analysis does not count the reduction of other oil heat emissions such as SOx, NOx and mercury. For purposes of this analysis, we assume that utilities pay for the infrastructure buildout and home and business owners pay for equipment conversion.

The largest increases in jobs, taxes and state gross domestic product occur from 2012 through 2021. In that time period:

- A total of 54,000 job-years of net total employment (8,000 jobs/year in the first five years and 3,100/year in years 6-10).
- $4.1 billion of increased net GDP over the expansion period ($2.8 billion first five years and $1.3 billion in the later years) and $0.4 billion of increased state revenue (86% realized in the first five years).

Once the expansion is completed in 2021, a set level of savings will accrue to customers and business owners:

- $250 million/year injected into Connecticut's economy (once program is in place) by saving residential customers up to $1,200 per year on their heating bills.

- $215 million/year reduction for commercial and industrial customers' production costs once program is in place.

From 2022 through 2050, the costs and benefits continue but at a lower level than during the first ten years. Table ES-1 summarizes the results over the entire period of analysis as annual average changes with respect to the baseline or no build forecast of the Connecticut economy.

Table ES-1: Annual Average Changes in Key Economic Variables: 2012 through 2050

Average Annual Change in Key Variables Above the Baseline: 2012-2050								
	Total Employment	Non-Farm Employment	Construction Jobs	Population	GDP (Millions 2010$)	Output (Millions 2010$)	Personal Income (Millions 2010$)	Net State Revenue (Millions 2010$)
On-Main Conversions								
All Counties	702	626	620	738	$95.22	$182.20	$86.33	$3.66
Fairfield	202	193	209	84	$25.38	$50.74	$23.80	$2.30
Hartford	166	143	157	218	$28.77	$54.83	$21.47	-$1.35
Litchfield	24	22	21	27	$1.59	$3.60	$3.11	$0.34
Middlesex	26	22	15	45	$3.29	$5.65	$4.08	$0.23
New Haven	243	217	191	290	$30.75	$58.10	$27.36	$1.75
New London	21	13	13	33	$4.24	$7.12	$2.86	$0.17
Tolland	15	12	9	32	$0.86	$1.42	$2.90	$0.14
Windham	6	5	5	9	$0.37	$0.79	$0.80	$0.07
Off-Main Extensions and Conversions								
Connecticut	513	448	657	612	$75.09	$176.56	$75.67	$6.19

Given the costs of conversion and the benefits realized by homeowners, their investment breaks even in six years. Similarly, commercial establishments converting to natural gas from oil realize an investment breakeven period of 7.4 years, while industrial customers break even on their investment in less than half a year.

As a result of these oil to gas conversions, Connecticut will have cleaner air, a lower carbon footprint and its businesses and homeowners will have lower production costs on the one hand and increased household consumption on the other. If the United States can tap further into its natural gas resources, conversion from oil to natural gas may in addition reduce our imports of oil and improve the nation's trade balance.

This analysis excludes the potential conversions from low-efficiency oil appliances to high-efficiency oil appliances because that analysis is beyond the scope of this work. Further, a new set of assumptions, costs and benefits needs to be determined for this type of conversion. There is no doubt that natural gas will not be available everywhere in Connecticut in the foreseeable future and therefore that oil conversions will undoubtedly occur. Such analysis is future work.

Overview

This project models a potential natural gas infrastructure build-out in Connecticut. While much of central Connecticut has gas service in the street (gas mains), there are potential gas customers in this region that have not connected with the mains in the street or converted their oil heating appliances to gas heating appliances. In addition, there are areas in Tolland, Windham and Litchfield counties for example where there are no mains. The natural gas infrastructure build-out occurs over a 10-year period and proceeds along two paths: "on-main conversions" and "off-main expansion."

"On-main conversions" occur from 2012 through 2021 and consist of connections of customers to existing nearby mains and conversion to gas appliances thus increasing the number of customers in Connecticut's existing natural gas service areas (see Figure 1). We present this analysis for each county.

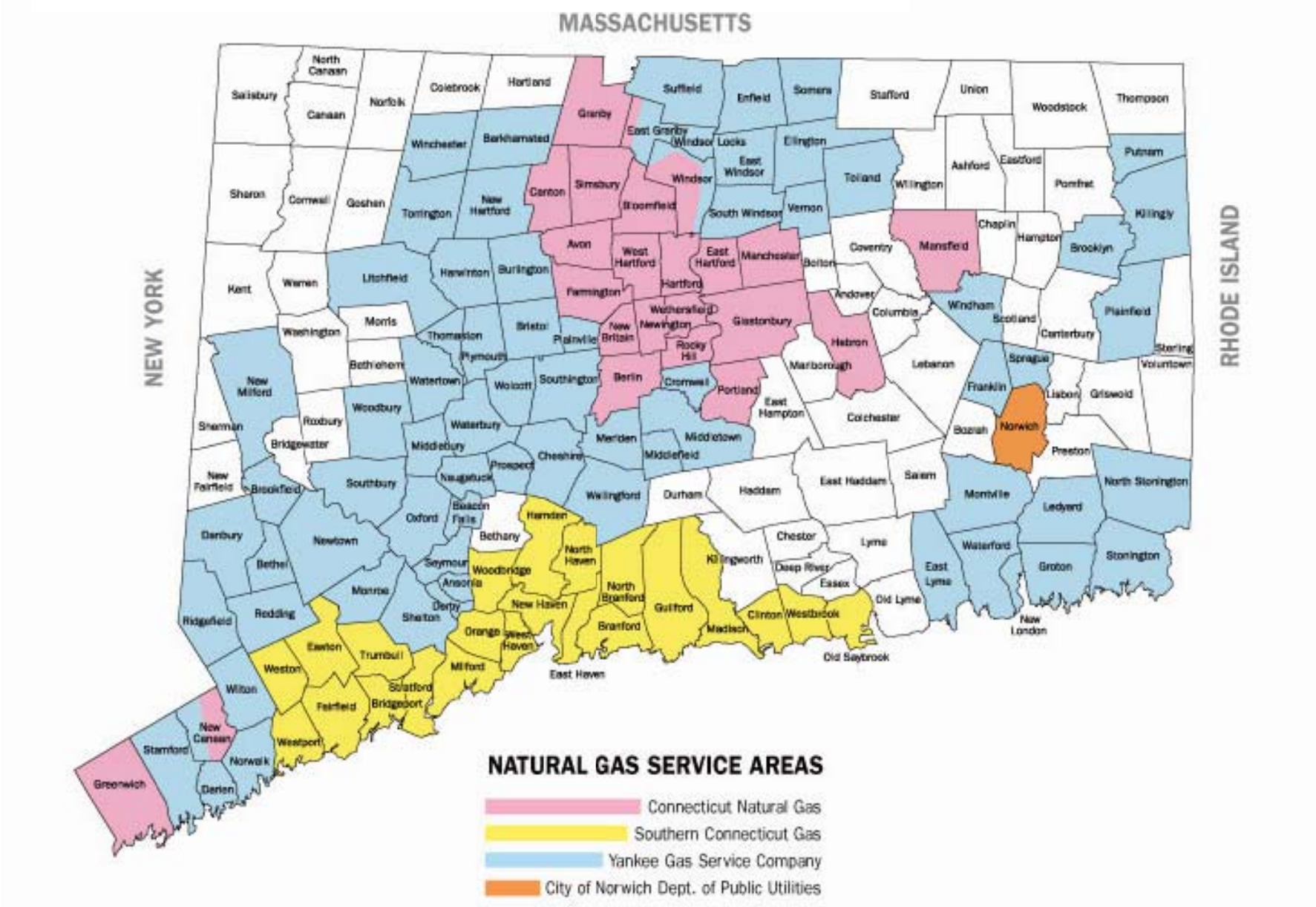
In addition and contemporaneously, "off-main expansion" occurs from 2012 through 2021. In the first five years (2012-2016), the gas companies extend mains into areas that offer the highest potential for conversion based on many factors including usage and density. Connections and conversions occur along the extended mains as service becomes available on a statewide basis from 2012 through 2021. For the purposes of the analysis, we assume that no further conversions occur after 2021 for customers on existing mains or along the new mains. DECD did not consider the potential for converting electric space heating as part of the analysis.

As conversions occur through 2021, the benefits of using natural gas accumulate annually as more customers switch from oil to natural gas. After 2021, the benefits of conversion described below continue through 2050 (the economic model's horizon) but do not accumulate because we assume that no new customers convert.

Funding for the gas infrastructure build-out comes from several sources. As the gas companies' customer base grows, there will be internal funding available from increased gas sales. In addition, the state will seek federal and private sector funding possibly including surcharges on gas ratepayers. As is generally the case today, the costs for connecting residences and businesses to mains would be primarily borne by the gas utilities and the costs of converting existing space and water heating equipment would be borne by home and business owners.

The benefits of converting from oil space and water heating equipment to gas space and water heating equipment are several. One benefit of conversion from oil to natural gas is that for a given heating requirement, natural gas is less expensive than oil per unit of fuel. Further, gas heating appliances are more efficient than oil heating appliances (that is, they convert more of the heat energy available per unit of fuel than oil appliances do and require less electricity to operate). Moreover, carbon emissions per unit of fuel is lower for natural gas than for oil-fired equipment and there is no NOx, SOx or mercury emitted with natural gas combustion. For the region, this implies that as conversion to natural gas from oil proceeds there will be less carbon emissions in the aggregate. Finally, the natural gas infrastructure build-out increases municipalities' grand lists by adding value to the properties it touches and by the taxes that gas utilities pay. As total energy costs decline because of conversion, households and businesses have more income to spend on other goods and services and the region becomes more competitive than it was with respect to other regions not making these investments.

Figure 1: Connecticut's Natural Gas Service Areas



Given the costs and the benefits mentioned, there is a net benefit after the investment in build-out, connection and conversion is amortized (see Tables 1, 2 and 3). However, other long-run costs must be considered. The residences and businesses that convert to gas will switch from their oil vendor to their natural gas supplier. There will be oil equipment installation, maintenance and oil appliance sales businesses that decline or collapse. Some of the labor released (e.g., HVAC workers) from declining businesses would be absorbed by the expanding natural gas heating business. Oil deliveries would decline and truck drivers, some of whom are part-time, would need to find new employment.

In this analysis, we assume there will be no significant resistance to extending gas mains because in many cases, extension will occur along approved rights of way (roads and streets). We assume there will be no significant permitting or siting issues as the infrastructure build-out progresses into new territory. We further assume that there will be sufficient gas supply as conversion increases. There are regional gas pipeline improvements in progress and the increasing Marcellus shale gas availability makes insufficient supply less probable as demand increases.[1]

The drivers of economic impact are construction (infrastructure build-out and household/business connection), appliance conversion (including equipment and new plumbing) and the operational efficiencies that allow consumers and businesses to reallocate their spending. In addition, we account for the negative impacts on the wholesale and retail oil business in each county.

Economics of Conversion

Connecticut's electric and gas utilities provided approximated costs per mile to extend natural gas mains and related equipment, costs for homes and businesses to connect to gas mains in the street as well as estimates of the costs of converting oil appliances to gas appliances (and related plumbing) for both hot water and space heating.

[1] See the Northeast Gas Association presentations from its 2011 Market Trends Forum, April 13, 2011 at http://66.241.193.5/index.php?option=com_content&task=view&id=228&Itemid=96.

For purposes of this analysis, we assume that the gas utilities contract with specialty trade contractors to connect residences and businesses with mains. The gas utilities pay for connections to mains; the 2011 estimated cost to install service and a meter is $4,283 for a residence and $7,669 for a commercial or industrial establishment. These costs escalate by 4% per year for ten years until 2021 when conversions are complete.

Homeowners and business owners pay to convert their oil heating appliances to gas heating appliances. HVAC contractors perform residential and commercial/industrial conversions and the gas utilities perform subsequent service and maintenance. As mains are extended, the gas utilities again contract with specialty trade contractors to do the excavating and pipe laying.

Residential

The costs and benefits of conversion for a 2,000 square foot (typical) residence in Connecticut appear in Table 1.

The analysis focuses on oil forced air/hot water/steam and high-efficiency gas forced air/hot water/steam residential heating systems. Other heating and cooling systems appear in Table 1 for comparison. In the first panel of Table 1, the electricity requirement for the standard residence is 1,143 kWh for an oil system and 486 kWh for a natural gas system. Cooling requirements are identical for each system and appear in the total kWh column. Annual oil consumption is 694 gallons (96,257,800 Btu) while natural gas consumption is 1,003 therms (100,300,000 Btu) or equivalently 1,123 cubic feet of natural gas. Note that the additional natural gas heat requirement arises because natural gas fuels other household appliances such as water heaters, cook stoves and dryers. Oil combustion generates 22.29 lbs/gallon of CO_2 while burning natural gas generates 12 lbs/therm. Therefore, heating the standard residence with oil generates 19,167 pounds of CO_2 annually and heating the same residence with natural gas generates 14,837 pounds of CO_2 annually.

The second panel of Table 1 summarizes the heating, cooling and fuel requirements for oil and natural gas from the first panel, while the third panel calculates the differences in energy requirements and costs between the two heating and cooling methods (cooling energy

requirements are identical for oil and gas systems and we ignore cooling energy requirements hereafter). The residential customer saves (does not use) 657 kWh of electricity saving $140 annually. The electric utility receives $140 less for distributing electric power to the residence to operate the gas heating equipment because the residence uses less electricity to heat with natural gas.

The 2011 cost of oil to heat the residence is $2,336 based on $3.37 per gallon and the 2011 cost of natural gas to heat the residence is $1,240 based on $1.24 per therm. The residential customer thus saves $1,096 (fuel cost) plus $134 (electricity savings) or $1,230 in 2011 by heating with natural gas. In addition, if CO_2 is priced initially at $3.75 per ton, there are additional benefits of $8.12 per residential customer in 2011 by generating fewer pounds of CO_2 for a total 2011 saving of $1,238.[2] If the cost to retrofit existing oil heating equipment with high-efficiency natural gas heating equipment is $7,500, the break-even period is six years assuming the conversion is completed in 2011. Panel 4 of Table 1 shows the net value to the gas and electric utilities.

[2] Currently, the Regional Greenhouse Gas Initiative price for CO_2 is about $2 per ton. This cost is passed through to electric ratepayers.

Table 1: Costs and Benefits of Converting from Oil to Natural Gas

2011 Oil Heat to High-Efficiency Gas Conversion Costs & Benefits for Typical 2,000 Sq. Ft. Home

Panel 1 System	Heating (kWh)	Total (kWh)	Oil (Gallons)	Natural Gas (Therms)	Pounds CO_2
Electric Baseboard and Standard AC	21,020	22,581	NA	NA	30,936
Oil Heat and Standard AC	1,143	2,706	694	NA	19,167
Gas Heat and Standard AC (83% eff.)	706	2,269	NA	1,123	16,588
High Eff. Gas Heat and Standard AC (93% eff.)	486	2,049	NA	1,003	14,837

2011 Delivered Fuel Prices*	
Electricity ($/kWh)	$0.2035
Nat. Gas ($/therm)	$1.24
Oil ($/gal)	$3.37

*EVA Forecast Residential CT

** CO_2 Rates	Value	Units
Electricity	1.37	lbs/kWh
Natural Gas	12	lbs/therm
Oil	22.29	lbs/gallon

** CO_2 Price ($/ton)
$16.00

***2010 CT IRP*

Panel 2 Convert (Oil System to Natural Gas)	Heating (kWh)	Total (kWh)	Oil (Gallons)	Natural Gas (Therms)	Pounds CO_2
Oil Heat and Standard AC	1,143	2,706	694	NA	19,167
High Eff. Gas and Standard AC	486	2,049	NA	1,003	14,837
Energy Difference	(657)	(657)	0	0	(4,330)
Total Cost	($98.96)	$416.83	$2,336.31	$1,240.36	$118.69
Customer Cost Difference		**($133.63)**	**($1,095.95)**		**($34.64)**

Electric & Gas Utilities' Value Difference		**($133.63)**		**$1,240.36**

Panel 3 System	Retrofit Cost	Annual Savings	ROI (years)
High Eff. Gas and Standard AC	$7,500	$1,264.22	5.93

Impact on the Consumer

Panel 4 Electric Utiltiy loss kWh ($)	Increase in Natural Gas Business	Difference
($133.63)	**$1,240.36**	**$1,106.73**

Net Value to Utilities

Commercial

We base the cost-benefit analysis for commercial and industrial customers appearing in Tables 2 and 3 on a standard or typical commercial or industrial establishment.[3] In the first panel of Table 2, the electrical heating requirement for the standard commercial establishment is 4,564 kWh for an oil system and 4,129 kWh for a natural gas system. Annual oil consumption is 1,248 gallons (173,097,600 Btu) while natural gas consumption is 1,262 therms (126,200,000 Btu) or equivalently 1,262 cubic feet of natural gas. Oil combustion generates 22.29 lbs/gallon of CO_2 while burning natural gas generates 12 lbs/therm. Therefore, heating the standard commercial establishment with oil generates

[3] New Jersey statutes define an industrial establishment by certain NAICS codes with exceptions (see http://www.nj.gov/dep/srp/regs/isra/isra_c.htm). A commercial establishment could be regarded as any other place of business. The utilities determined the typical commercial and industrial establishments based on their customer data.

34,070 pounds of CO_2 annually and heating the same establishment with natural gas generates 20,795 pounds of CO_2 annually.

The second panel of Table 2 summarizes the heating, cooling and fuel requirements for oil and natural gas from the first panel, while the third panel calculates the differences in energy requirements and costs between the two heating methods. The commercial customer saves (does not use) 435 kWh of electricity saving $75 in 2011. The electric utility receives $75 less for distributing the required electric power to the commercial establishment to operate the gas heating equipment. The 2011 cost of oil to heat the commercial establishment is $3,879 based on $3.11 per gallon and the 2011 cost of natural gas to heat the commercial establishment is $1,235 based on $0.98 per therm. The commercial customer thus saves $2,644 (fuel cost) plus $75 in electricity savings or $2,719 in 2011 by heating with natural gas. In addition, if CO_2 is priced initially at $3.75 per ton, additional savings per commercial customer are $25 in 2011 by generating fewer pounds of CO_2 for a total annual saving of $2,744 (see footnote 2). If the cost to retrofit existing oil heating equipment with high-efficiency natural gas heating equipment is $20,300, the break-even period is 7.4 years assuming the conversion is completed in 2011.

Table 2: Costs and Benefits of Converting from Oil to Natural Gas

2011 Oil Heat to High-Efficiency Gas Conversion Costs & Benefits for Typical Commercial Establishment

Panel 1 System	Total (kWh)	Oil (Gallons)	Natural Gas (Therms)	Pounds CO_2
Oil Heat	4,564	1,248	NA	34,070
High Eff. Gas Heat (93% eff.)	4,129	NA	1,262	20,795

2011 Delivered Fuel Prices*		** CO_2 Rates	Value	Units
Electricity ($/kWh)	$0.1720	Electricity	1.37	lbs/kWh
Nat. Gas ($/therm)	$0.98	Natural Gas	12	lbs/therm
Oil ($/gal)	$3.11	Oil	22.29	lbs/gallon

*EVA Forecast Commercial CT

** CO_2 Price / ton
$16.00

***2010 CT IRP*

Panel 2 Convert (Oil System to Natural Gas)	Total (kWh)	Oil (Gallons)	Natural Gas (Therms)	Pounds CO_2
Oil Heat	4,564	1,248	NA	34,070
High Eff. Gas Heat (93% eff.)	4,129	NA	1,262	20,795
Energy & CO2 Difference	(435)	0	0	(13,275)
Total Cost	$710.06	$3,878.76	$1,234.51	$166.36
Customer Cost Difference	($74.74)	($2,644.25)		($106.20)

Electric & Gas Utilities' Value Difference	($74.74)		$1,234.51

Panel 3 System	Retrofit Cost	Annual Savings	ROI (years)
High Eff. Gas Heat	$20,300	$2,825	7.19

Impact on the Business

Panel 4 Electric Utiltiy loss kWh ($)	Increase in Natural Gas Business	Difference
($74.74)	$1,234.51	$1,159.77

Net Value to Utilities

Industrial

For a typical industrial customer, the first panel of Table 3 shows the heating requirement for the standard industrial establishment is 9,776 kWh for an oil system and 8,845 kWh for a high-efficiency natural gas system. Annual oil consumption is 16,418 gallons (2,277,176,600 Btu) while natural gas consumption is 9,715 therms (971,500,000 Btu) or equivalently 9,715 cubic feet of natural gas. Oil combustion generates 22.29 lbs/gallon of CO_2 while burning natural gas generates 12 lbs/therm. Therefore, heating the standard industrial establishment with oil generates 379,350 pounds of CO_2 annually and heating the same establishment with natural gas generates 128,697 pounds of CO_2 annually.

The second panel of Table 3 summarizes the heating, cooling and fuel requirements for oil and natural gas from the first panel, while the third panel calculates the differences in energy requirements and costs between the two heating methods. The industrial customer saves (does not use) 931 kWh of electricity saving $137 in 2011. The electric utility receives $137 less for distributing the required electric power to the industrial establishment to operate the gas heating equipment. The 2011 cost of oil to heat the industrial establishment is $50,150 based on $3.05 per gallon and the 2011 cost of natural gas to heat the industrial establishment is $7,795 based on $0.80 per therm. The industrial customer thus saves $42,356 (fuel cost) plus $137 in electricity savings or $42,493 in 2011 by heating with natural gas. In addition, if CO_2 is priced initially at $3.75 per ton, additional savings per industrial customer are $470 in 2011 by generating fewer pounds of CO_2 for a total annual saving of $42,963 (see footnote 2). If the cost to retrofit existing oil heating equipment with high-efficiency natural gas heating equipment is $20,300, the break-even period is 0.47 years assuming the conversion is completed in 2011.

Table 3: Costs and Benefits of Converting from Oil to Natural Gas

2011 Oil Heat to High-Efficiency Gas Conversion Costs & Benefits for Typical Industrial Establishment

Panel 1 System	Total (kWh)	Oil (Gallons)	Natural Gas (Therms)	Pounds CO_2
Oil Heat	9,776	16,418	NA	379,350
High Eff. Gas Heat (93% eff.)	8,845	NA	9,715	128,697

2011 Delivered Fuel Prices*		** CO_2 Rates	Value	Units
Electricity ($/kWh)	$0.1472	Electricity	1.37	lbs/kWh
Nat. Gas ($/therm)	$0.80	Natural Gas	12	lbs/therm
Oil ($/gal)	$3.05	Oil	22.29	lbs/gallon

*EVA Forecast Industrial CT

** CO_2 Price / ton
$16.00

***2010 CT IRP*

Panel 2 Convert (Oil System to Natural Gas)	Total (kWh)	Oil (Gallons)	Natural Gas (Therms)	Pounds CO_2
Oil Heat	9,776	16,418	NA	379,350
High Eff. Gas Heat	8,845	NA	9,715	128,697

Energy & CO2 Difference	(931)	0	0	(250,653)
Total Cost	$1,302.12	$50,150	$7,795	$1,030
Customer Cost Difference	($137.06)	($42,356)		($2,005)

Electric & Gas Utilities' Value Difference	($137.06)		$7,794.81

Panel 3 System	Retrofit Cost	Annual Savings	ROI (years)
High Eff. Gas Heat	$20,300	$44,497.92	0.46

Impact on the Business

Panel 4 Electric Utiltiy loss kWh ($)	Increase in Natural Gas Business	Difference
($137.06)	$7,794.81	$7,657.74

Net Value to Utilities

Economic Impact

As natural gas displaces oil in each county, the composition of energy consumption in the region changes. Oil companies will lose business equal to the dollars their converting customers spent on oil, and gas utilities will gain business equal to net new gas consumption due to conversion. HVAC dealers as well as the gas utilities selling and servicing gas heating systems will experience increased business and may absorb some capital and labor assets from declining companies selling fuel oil and selling and servicing oil appliances. Consumers' disposable income in the region will increase and businesses' production costs will decline as they convert from oil to natural gas. These benefits accumulate over time as new customers continue to convert through 2021. During the installation of new mains, construction jobs will increase and as residences, commercial and industrial establishments

connect to mains and install gas heating appliances, certain construction jobs and HVAC businesses will grow.

Tables 1, 2 and 3 present a 2011 snapshot of the costs and benefits of converting from oil to gas in any Connecticut county as we assume the costs itemized in the tables occur with small variance across the state. The gas and electric utilities estimated the number of conversions by county by type of establishment and residence for the two five-year periods of conversions on existing mains. Table 6 on page 19 shows the numbers of new residential, commercial and industrial customers expected to connect to existing mains and convert their appliances in the first and second five-year periods in each county. Table 4 shows the expected miles of new mains installed and the numbers of new residential, commercial and industrial customers expected to connect to new mains and convert their appliances in the first and second five-year periods in the state as a whole. We assume that 20% of the estimated converting customers connect and convert each year in each period.

Table 4: Off-Main Conversions and Costs

Costs & Market	Residential	Commercial	Industrial	total
	Off-main	Off-main	Off-main	Off-main
# of services (customers) added in years 0-5	15,452	11,200	129	26,781
# of services (customers) added in years 6-10	36,054	26,133	301	62,488
Miles of main added in years 0-5	517.3	374.9	4.3	896.5
Cost per mile	$1,033,333	$1,033,333	$1,033,333	$926,382,637

Table 5 shows prices for electricity, natural gas, oil as they escalate according to the EVA[4] forecasts. The price for CO_2 escalates at 7% per year according to Connecticut's Integrated Resource Plans.[5] We apportion prices for retrofitting oil with gas appliances into 60% for labor and 40% for materials (these are the costs of conversion inside the building). Labor costs escalate at 3.5% per year while materials costs escalate at 2% per year. Given these assumptions, we calculate the weighted average costs for retrofitting from 2012 through 2050. We calculate inflation factors using the EVA forecasts in Table 6 and use the

[4] Energy Ventures Analysis of Arlington, VA prepared these forecasts for the NU Service Company.
[5] IRP for Connecticut, January 1, 2008, prepared by the Brattle Group, http://www.brattle.com/_documents/UploadLibrary/Upload656.pdf. IRP for Connecticut, January 1, 2009, prepared by The Brattle Group, http://www.brattle.com/_documents/UploadLibrary/Upload735.pdf. 2010 Connecticut Integrated Resource Plan: Policy and Technology Options for Repowering Connecticut's Generation Fleet, Whitepaper prepared for the Connecticut Energy Advisory Board by NRG Energy, Inc. January 7, 2010. Available at http://www.ctenergy.org/pdf/NRGWP.pdf.

geometric mean of the series of inflation factors as the constant growth factor for oil, natural gas, electricity and CO_2 to inflate their prices from 2042 through 2050 using the 2041 price as the base.

Table 5: Future Prices of Fuel, Electricity and CO_2

Energy Component By Year		Natural Gas Residential	Natural Gas Commercial	Natural Gas Industrial	Electricity Residential	Electricity Commercial	Electricity Industrial	Oil Residential	Oil Commercial	Oil Industrial	CO2
			per MMBtu			per kwh			per MMBtu		per ton
Prices	2011	$12.37	$9.79	$8.02	$0.20	$0.17	$0.15	$24.29	$22.41	$22.02	
	2012	$12.49	$9.86	$8.02	$0.22	$0.18	$0.17	$24.10	$22.20	$21.81	$16.81
	2013	$12.84	$10.16	$8.29	$0.23	$0.19	$0.17	$23.07	$21.14	$20.74	$18.31
	2014	$13.37	$10.64	$8.74	$0.23	$0.19	$0.18	$27.67	$25.71	$25.30	$20.70
	2015	$14.12	$11.35	$9.42	$0.24	$0.20	$0.18	$28.05	$26.06	$25.65	$23.19
	2016	$14.50	$11.69	$9.74	$0.25	$0.21	$0.19	$28.45	$26.43	$26.01	$25.80
	2017	$14.88	$12.04	$10.06	$0.25	$0.21	$0.19	$28.85	$26.80	$26.38	$28.53
	2018	$15.27	$12.40	$10.39	$0.25	$0.21	$0.19	$29.27	$27.19	$26.77	$31.68
	2019	$15.76	$12.86	$10.83	$0.26	$0.22	$0.20	$29.86	$27.77	$27.34	$34.97
	2020	$16.26	$13.33	$11.28	$0.26	$0.22	$0.20	$30.46	$28.34	$27.91	$38.40
	2021	$16.49	$13.53	$11.46	$0.27	$0.23	$0.21	$31.14	$29.00	$28.56	$41.99
	2022	$16.92	$13.93	$11.84	$0.28	$0.23	$0.21	$31.71	$29.54	$29.10	$45.73
	2023	$17.36	$14.34	$12.23	$0.29	$0.24	$0.22	$32.31	$30.12	$29.68	$49.63
	2024	$17.82	$14.77	$12.64	$0.29	$0.24	$0.22	$32.96	$30.75	$30.30	$53.69
	2025	$18.26	$15.18	$13.04	$0.30	$0.25	$0.23	$33.61	$31.38	$30.92	$57.93
	2026	$18.69	$15.58	$13.42	$0.31	$0.26	$0.23	$34.28	$32.03	$31.57	$62.35
	2027	$19.16	$16.03	$13.85	$0.32	$0.26	$0.24	$34.95	$32.67	$32.20	$66.95
	2028	$19.64	$16.48	$14.29	$0.33	$0.27	$0.24	$35.63	$33.33	$32.86	$71.74
	2029	$20.13	$16.95	$14.74	$0.33	$0.27	$0.25	$36.34	$34.02	$33.54	$76.74
	2030	$20.63	$17.42	$15.20	$0.34	$0.28	$0.26	$37.05	$34.71	$34.23	$81.93
	2031	$21.14	$17.91	$15.67	$0.35	$0.29	$0.26	$37.78	$35.42	$34.93	$87.34
	2032	$21.67	$18.41	$16.17	$0.36	$0.29	$0.27	$38.53	$36.14	$35.65	$93.45
	2033	$22.21	$18.93	$16.68	$0.37	$0.30	$0.27	$39.29	$36.87	$36.38	$99.99
	2034	$22.76	$19.46	$17.20	$0.38	$0.31	$0.28	$40.06	$37.62	$37.12	$106.99
	2035	$23.33	$20.01	$17.74	$0.39	$0.31	$0.29	$40.85	$38.39	$37.89	$114.48
	2036	$23.91	$20.57	$18.30	$0.40	$0.32	$0.29	$41.65	$39.17	$38.66	$122.50
	2037	$24.50	$21.15	$18.87	$0.41	$0.33	$0.30	$42.47	$39.97	$39.46	$131.07
	2038	$25.11	$21.75	$19.46	$0.42	$0.34	$0.31	$43.31	$40.78	$40.26	$140.25
	2039	$25.74	$22.36	$20.08	$0.43	$0.34	$0.31	$44.16	$41.61	$41.09	$150.06
	2040	$26.38	$22.99	$20.71	$0.44	$0.35	$0.32	$45.03	$42.46	$41.93	$160.57
	2041	$27.04	$23.63	$21.36	$0.45	$0.36	$0.33	$45.92	$43.32	$42.79	$171.81
Forecast sources		EVA forecast 2011-2021 inflation 2022+			EVA forecast 2011-2021 inflation 2022+			EVA forecast 2011-2021 inflation 2022+			2010 IRP 2012-2031 inflation 2032+
	2042	$27.75	$24.34	$22.06	$0.46	$0.37	$0.34	$46.90	$44.29	$43.75	$186.15
	2043	$28.48	$25.06	$22.80	$0.48	$0.38	$0.35	$47.91	$45.27	$44.73	$201.68
	2044	$29.23	$25.81	$23.55	$0.49	$0.39	$0.35	$48.94	$46.28	$45.73	$218.51
	2045	$30.01	$26.58	$24.33	$0.50	$0.40	$0.36	$49.99	$47.30	$46.76	$236.74
	2046	$30.80	$27.37	$25.14	$0.51	$0.41	$0.37	$51.06	$48.36	$47.80	$256.50
	2047	$31.61	$28.19	$25.97	$0.53	$0.42	$0.38	$52.16	$49.43	$48.87	$277.91
	2048	$32.44	$29.03	$26.84	$0.54	$0.43	$0.39	$53.27	$50.53	$49.97	$301.10
	2049	$33.30	$29.89	$27.73	$0.56	$0.44	$0.41	$54.42	$51.65	$51.09	$326.23
	2050	$34.18	$30.79	$28.65	$0.57	$0.45	$0.42	$55.59	$52.80	$52.23	$353.45

We model the increase in disposable income as increased spending in all other household consumption categories commensurate with established spending patterns.[6] Each cost and benefit accumulates annually for ten years as more households convert to gas at which time

[6] The Consumer Expenditure Survey establishes spending patterns for households with different incomes and householder ages (see http://www.bls.gov/cex).

(2022) the costs and benefits increase at the rate of inflation of the relevant price through 2050 (oil, electricity, natural gas and the dollar value of total consumer gain).
The money businesses save by converting to natural gas reduces their production costs and makes them more competitive relative to their peers and competitors in other states. We calculate the reduction in production costs as the ratio of the total savings of commercial and industrial customers to the output (sales or value of shipments) of all industries in the county. This quantity represents the proportion of reduced production costs all industries in each county share and we calculate the ratio each year based on the relevant forecast commodity prices.

Spending declines on oil and electricity and spending increases for gas accumulate each year as more commercial and industrial customers convert. Accumulation ceases in 2021 when conversion activity ceases. From 2021 through 2050, the nominal costs and benefits increase at the rate of inflation of the relevant price (oil, electricity, natural gas and the personal consumption expenditure index that inflates industry output).

Drivers of Economic Impact

The basis for net new economic activity is the number on- and off-main conversions to occur between 2012 and 2021 inclusive. Table 6 shows the gas utilities' current and estimated customers in each county in each sector and the rates of conversion for prospective on-main and off-main customers. There is significant variation by county and customer type. For the state as a whole, the share of on-main residential and commercial prospects converting to natural gas is close to 18%, while these shares are 5.7% for off-main residential prospects and 43% for off-main commercial prospects. This suggests that there may be more pent up demand for natural gas in the commercial market than in the residential market where gas cannot currently be found. For the state as a whole, the share of industrial prospects for on-main conversions is 27% and the share for off-main conversions is 20%. These estimates represent consensus marketing intelligence in the state's gas and electric utilities.

The number of expected conversions for on-main prospects drives the changes in spending and saving (expressed as increased household consumption and reduced production costs) by county each year for each sector (residential, commercial and industrial). The number of expected conversions for off-main prospects drives the changes in spending and saving in the state as a whole each year for each sector.

Table 6: Prospective Customer Expected Conversion Rates

Residential

County	Total	Current Customers	Total prospects (non-cust)	Prospective on-main adds	Percent of Prospects for on-main adds	Prospective off-main adds	Percent of Prospects for off-main adds
Fairfield	293,463	129,630	163,833	42,949	26.22%	9,307	5.7%
Hartford	480,743	165,816	314,927	55,092	17.49%	17,891	5.7%
Litchfield	64,166	11,262	52,904	2,763	5.22%	3,006	5.7%
Middlesex	77,604	8,301	69,303	2,434	3.51%	3,937	5.7%
New Haven	310,941	147,757	163,184	54,131	33.17%	9,271	5.7%
New Londo	70,826	8,705	62,121	2,015	3.24%	3,529	5.7%
Tolland	55,580	5,431	50,149	955	1.90%	2,849	5.7%
Windham	35,204	5,003	30,201	512	1.70%	1,716	5.7%
Total	1,388,527	481,906	906,621	160,852	17.74%	51,506	5.7%

Commercial

County	Total	Current Customers	Total prospects (non-cust)	Prospective on-main adds	Percent of Prospects for on-main adds	Prospective off-main adds	Percent of Prospects for off-main adds
Fairfield	31,416	12,413	19,002	5,536	29.13%	8,218	43.2%
Hartford	43,366	14,314	29,053	3,886	13.37%	12,564	43.2%
Litchfield	7,364	1,335	6,028	753	12.49%	2,607	43.2%
Middlesex	8,684	1,408	7,276	436	5.99%	3,146	43.2%
New Haven	27,526	14,763	12,764	4,088	32.03%	5,520	43.2%
New Londo	7,226	1,508	5,718	549	9.60%	2,473	43.2%
Tolland	4,516	831	3,685	198	5.39%	1,594	43.2%
Windham	3,538	736	2,801	139	4.98%	1,212	43.2%
Total	133,636	47,309	86,327	15,585	18.05%	37,333	43.2%

Industrial

County	Total	Current Customers	Total prospects (non-cust)	Prospective on-main adds	Percent of Prospects for on-main adds	Prospective off-main adds	Percent of Prospects for off-main adds
Fairfield	812	607	205	97	47.36%	42	20.3%
Hartford	1,495	736	759	216	28.40%	154	20.3%
Litchfield	210	112	99	17	17.53%	20	20.3%
Middlesex	298	38	260	18	6.84%	53	20.3%
New Haven	1,247	733	514	201	39.05%	104	20.3%
New Londo	127	28	99	13	12.78%	20	20.3%
Tolland	106	44	62	5	7.53%	13	20.3%
Windham	171	52	119	3	2.69%	24	20.3%
Total	4,467	2,351	2,116	569	26.89%	430	20.3%

Total All Sectors

County	Total	Current Customers	Total prospects (non-cust)	Prospective on-main adds	Percent of Prospects for on-main adds	Prospective off-main adds	Percent of Prospects for on-main adds
Fairfield	325,691	142,650	183,040	48,582	26.54%	17,567	9.6%
Hartford	525,605	180,866	344,739	59,193	17.17%	30,610	8.9%
Litchfield	71,740	12,709	59,031	3,533	5.99%	5,633	9.5%
Middlesex	86,586	9,747	76,839	2,888	3.76%	7,136	9.3%
New Haven	339,715	163,254	176,461	58,419	33.11%	14,895	8.4%
New Londo	78,178	10,241	67,937	2,577	3.79%	6,022	8.9%
Tolland	60,202	6,307	53,895	1,158	2.15%	4,455	8.3%
Windham	38,913	5,792	33,122	655	1.98%	2,951	8.9%
Total	1,526,630	531,566	995,064	177,006	17.79%	89,269	9.0%

We summarize the foregoing discussion of costs and benefits in four charts. Each chart shows the time pattern and magnitude of the increases and decreases in spending and the net benefits in terms of increased household spending and reduced production cost. Chart 1 shows the changes in spending by on-main residential prospects converting at the state level and the increase in household spending as a result of their savings from conversion. Chart 2 shows the changes in spending from on-main conversions of commercial and industrial prospects at the state level as well as the reduction in their production costs as a result of their savings from conversion. Charts 1 and 2 shows the county changes in spending aggregated to the state level for brevity.

Chart 3 shows the changes in spending for off-main conversion of residential prospects at the state level. Chart 4 shows the changes in spending for off-main conversions of commercial and industrial prospects at the state.

The charts reflect the patterns of new spending and saving implied by the numbers of prospects converting, the costs of conversion, the value of natural gas purchased, the value of oil not purchased, the value of electricity not purchased and the value of new household consumption and the dollar value of reduced production costs for commercial and industrial converts. For on-main conversions, the charts show the direct costs and benefits at the state level for which county costs and benefits have been aggregated. For off-main conversions, the charts show state-level costs and benefits because the data is provided at the state level in this case.

Chart 1: Changes in Spending and Saving for On-main Residential Prospects

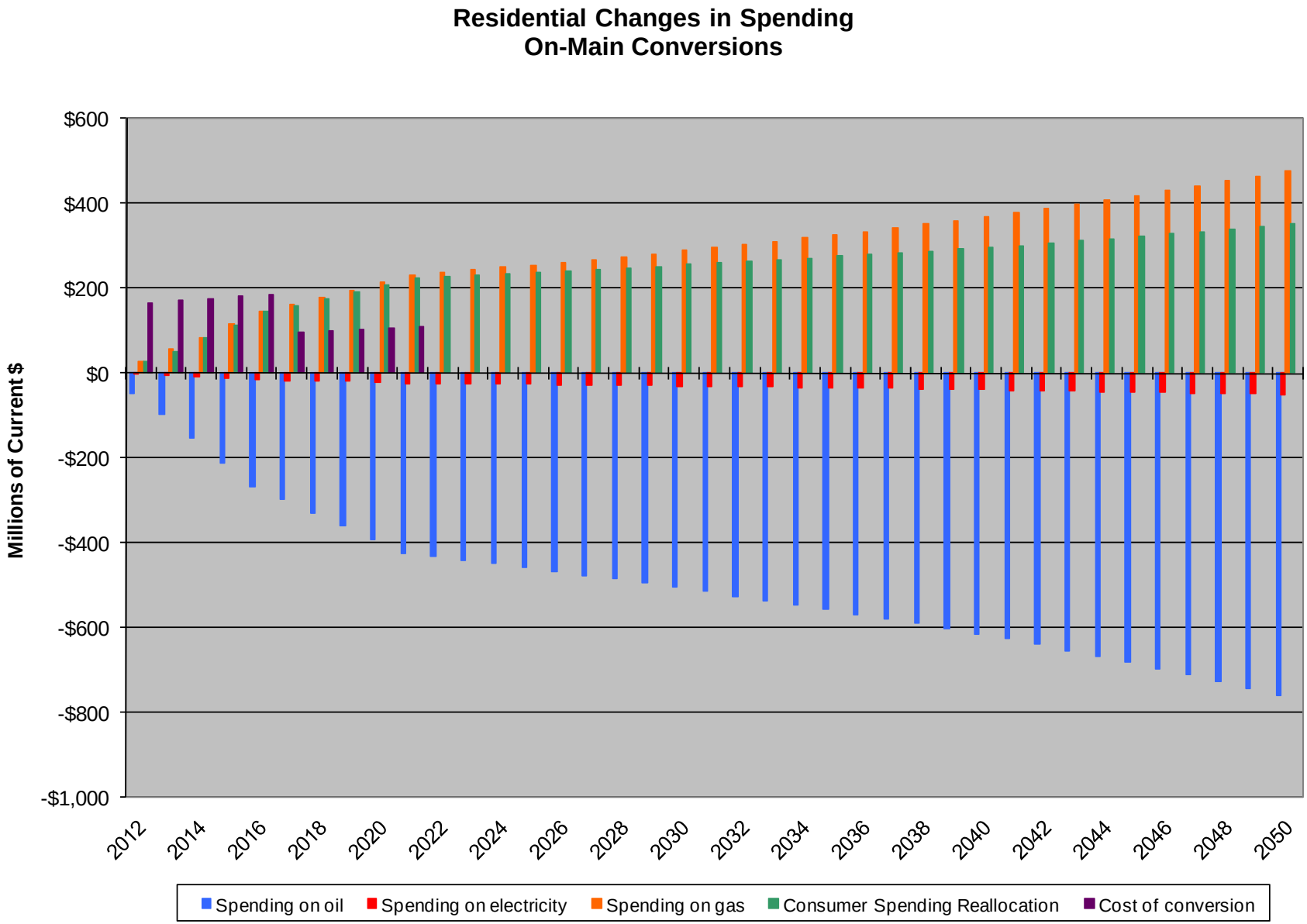


Chart 2: Changes in Spending and Saving for On-main Commercial and Industrial Prospects

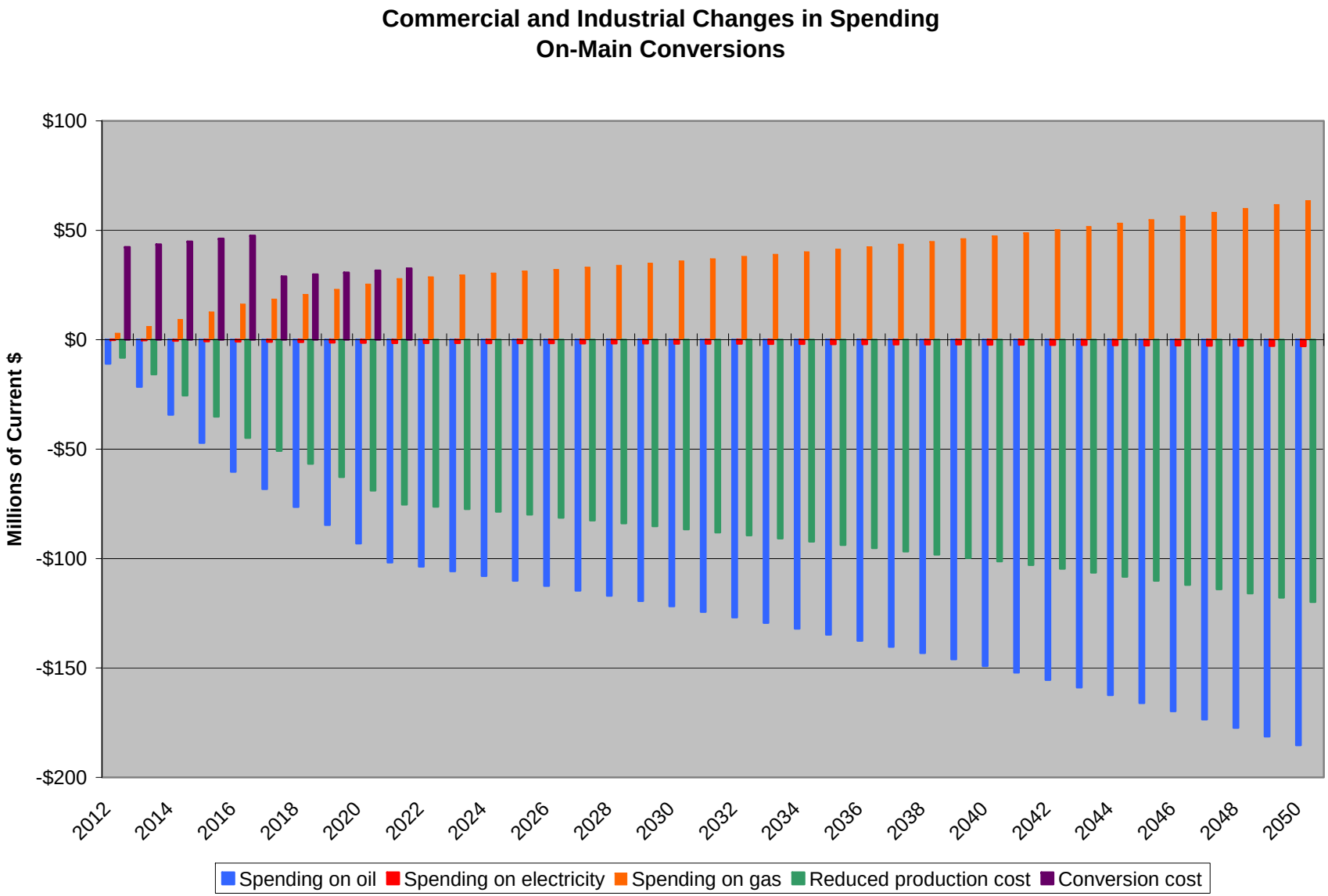


Chart 3: Changes in Spending and Saving for Off-main Residential Prospects

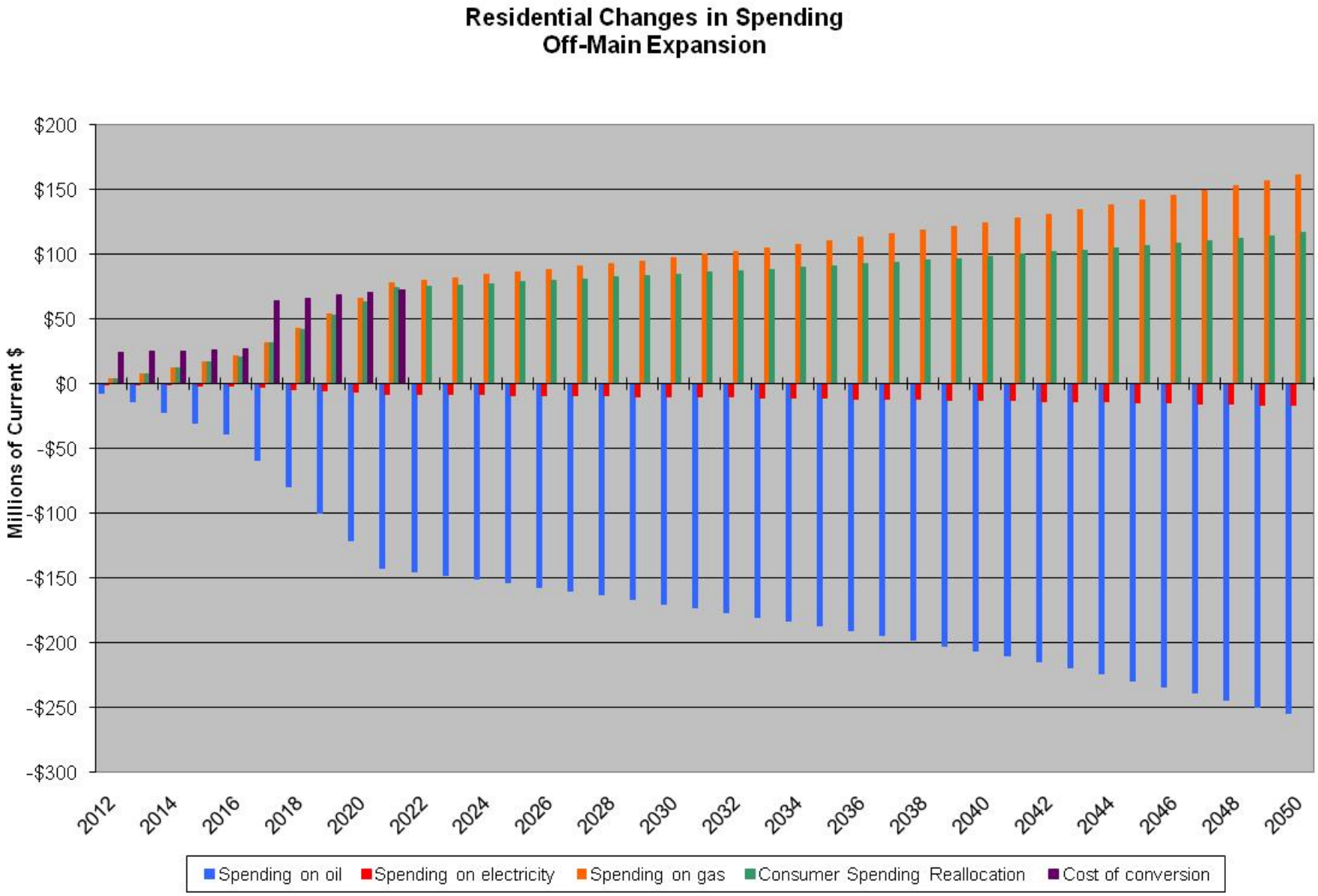
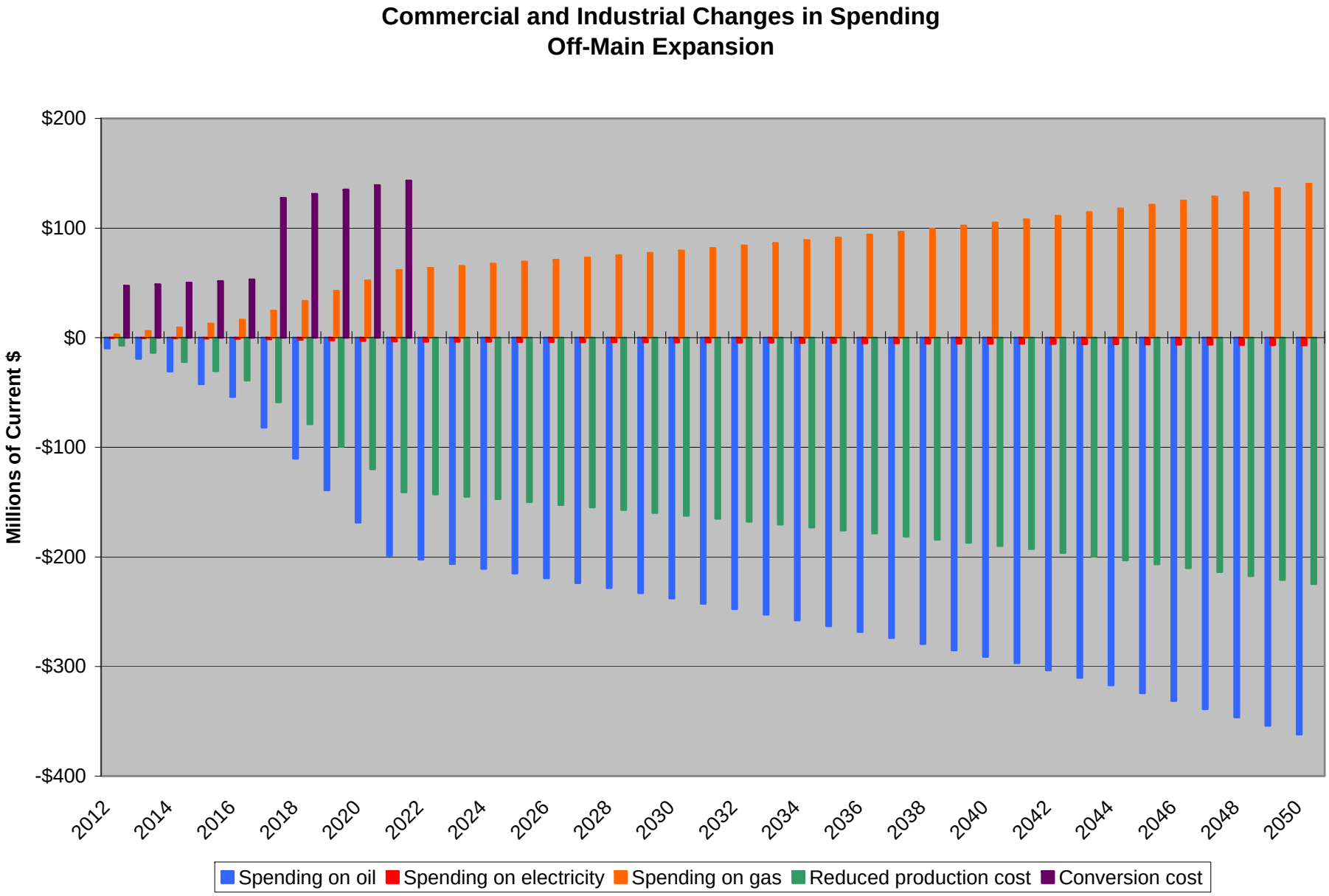


Chart 4: Changes in Spending and Saving for Off-main Commercial and Industrial Prospects



Economic Analysis Results

Table 7 summarizes the economic impact of the proposed buildout of the state's natural gas infrastructure between 2012 and 2050. The numbers in the table reflect the annual average changes from the baseline or no-build forecast of the Connecticut economy. These results reflect the net, economy-wide result of reduced spending for oil and electricity, increased spending for natural gas and appliance conversion as well as the increased spending by households and reduced production costs of all industries in the state. Total employment includes payroll jobs (including the public sector, sole proprietors and independent contractors). Non-farm employment includes payroll employment without farm jobs. State gross domestic product (GDP) is the value of goods and services produced in the state in a year. Output represents the value of shipments and/or sales of all industries in the state. Personal income represents income from all sources including wage and salary disbursements, dividends, interest and capital gains, alimony, prize winnings and gifts more than $10,000. Net state revenue represents the difference between revenue from all domestic sources and expenditure for all domestic uses at the state level.

Table 7: Annual Average Changes in Key Economic Variables: 2012 through 2050

Average Annual Change in Key Variables Above the Baseline: 2012-2050								
	Total Employment	Non-Farm Employment	Construction Jobs	Population	GDP (Millions 2010$)	Output (Millions 2010$)	Personal Income (Millions 2010$)	Net State Revenue (Millions 2010$)
On-Main Conversions								
All Counties	702	626	620	738	$95.22	$182.20	$86.33	$3.66
Fairfield	202	193	209	84	$25.38	$50.74	$23.80	$2.30
Hartford	166	143	157	218	$28.77	$54.83	$21.47	-$1.35
Litchfield	24	22	21	27	$1.59	$3.60	$3.11	$0.34
Middlesex	26	22	15	45	$3.29	$5.65	$4.08	$0.23
New Haven	243	217	191	290	$30.75	$58.10	$27.36	$1.75
New London	21	13	13	33	$4.24	$7.12	$2.86	$0.17
Tolland	15	12	9	32	$0.86	$1.42	$2.90	$0.14
Windham	6	5	5	9	$0.37	$0.79	$0.80	$0.07
Off-Main Extensions and Conversions								
Connecticut	513	448	657	612	$75.09	$176.56	$75.67	$6.19

<u>On-main Conversions</u>

Chart 5 shows the timepath of job changes with respect to the baseline forecast. The pattern reflects the two five-year periods of accumulating costs and benefits. Note that the majority of the new jobs in the first ten years accrues to the construction industry. That total and non-farm

employment dips below the baseline forecast reflects the sudden halt to on-main conversions in 2022. From 2023 through 2029, job seekers and jobholders attracted to the state because of increased economic activity find themselves out of work. This includes many in the oil delivery and service industry that is classified as non-store retailers. Gradually the economy grows and reaches a new, higher long-run equilibrium as the benefits from conversion overtake the losses.

Chart 6 shows the timepath of changes in state GDP, output, personal income and net state revenue. The pattern of changes in these variables reflects the two five-year periods of on-main conversion activity across the state. Net state revenue dips below the baseline forecast from 2022 through 2029 as workers without jobs seek state assistance. The state economy rebounds as new natural gas users realize the benefits of conversion and the economy reaches a new, higher long-run equilibrium as the benefits from conversion overtake the losses.

Chart 7 shows the timepath of changes in Connecticut's imports of oil, natural gas and pipeline and truck transportation. The reduction in the state's use of oil reflects in the decline below the baseline forecast of the 'Petroleum and coal product manufacturing' industry's imports. As Connecticut does not manufacture petroleum products and imports what it consumes, the reduction in oil consumption reduces oil imports in turn. The increased use of natural gas reflects in the increased import of 'Utilities' and 'Pipeline transportation' representing the higher inflow of natural gas to the state and the increased service business of the gas utilities.

Off-main expansion

For the off-main conversions, Charts 8, 9 and 10 depict the same variables and patterns of these variables' evolution (for the same reasons) as in Charts 5, 6 and 7. These results reflect different numbers of conversions in the three sectors statewide that Table 6 illustrates and the additional construction spending required to extend mains into areas previously without them. As mains are extended, conversions proceed as natural gas service becomes available. In Charts 7 and 10, imports of petroleum products first rise above the baseline forecast and then decline below the baseline forecast and rise slowly towards the baseline after 2022. The initial and short-term rise in oil imports despite the decline in spending on oil is due to the increased economic activity as conversions and main extensions commence. Within a year or two, the

decline in spending for oil overwhelms new economic activity and imports decline for several years. The gradual rise in imports after conversions cease in 2021 occurs because the economy continues to grow and oil imports slowly increase. The projected increase after 2021 in oil usage is based on currently available, historical modeling data. Under this gas expansion scenario, however, the increase in energy usage will likely be divided between oil and gas, resulting in a smaller rebound for oil.

Chart 5: Timepath of Job Creation for On-Main Conversions

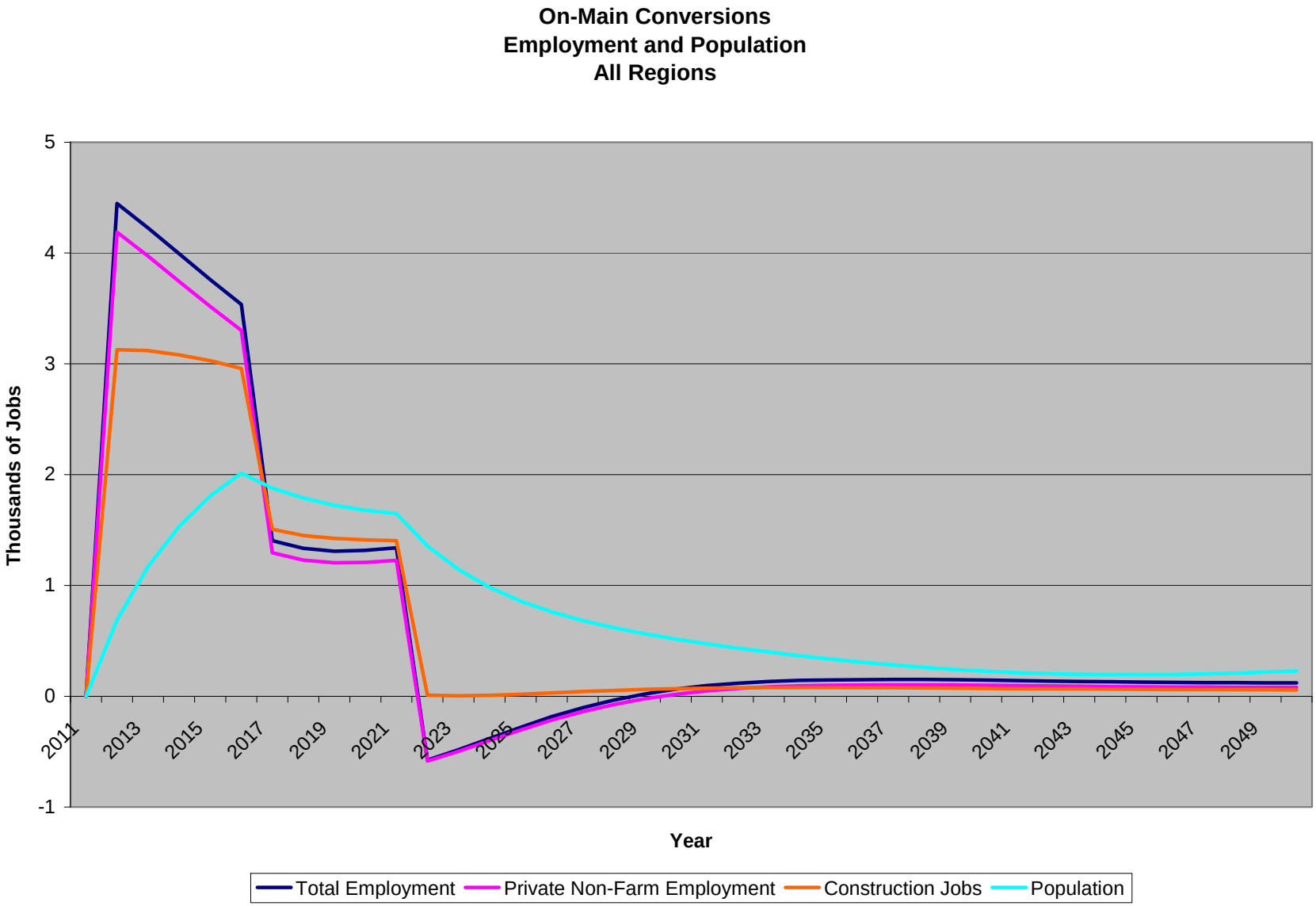


Chart 6: Timepath of Changes in State GDP, Output, Personal Income and Net State Revenue for On-Main Conversions

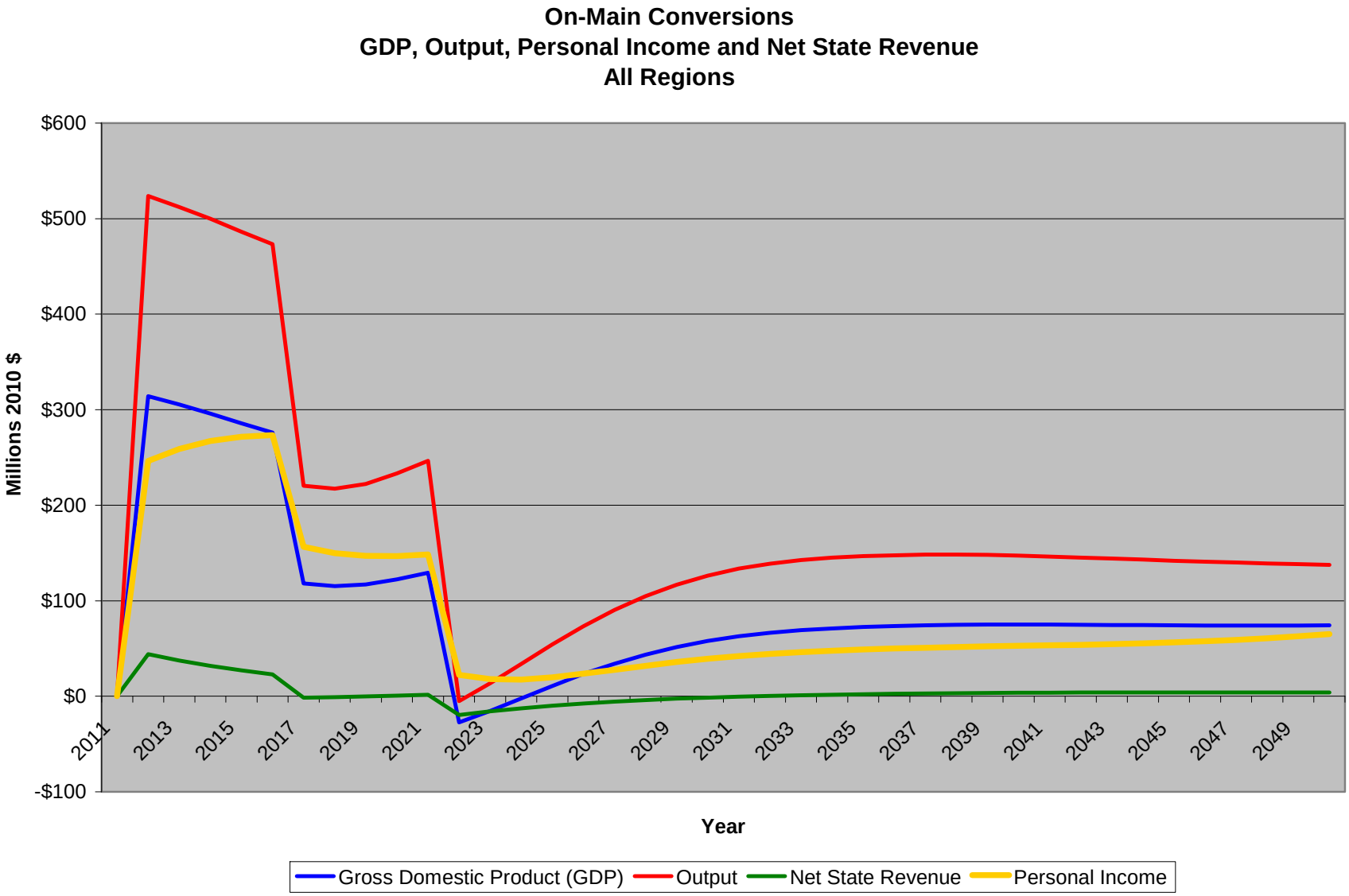


Chart 7: Timepath of Changes in Connecticut's Imports for On-Main Conversions

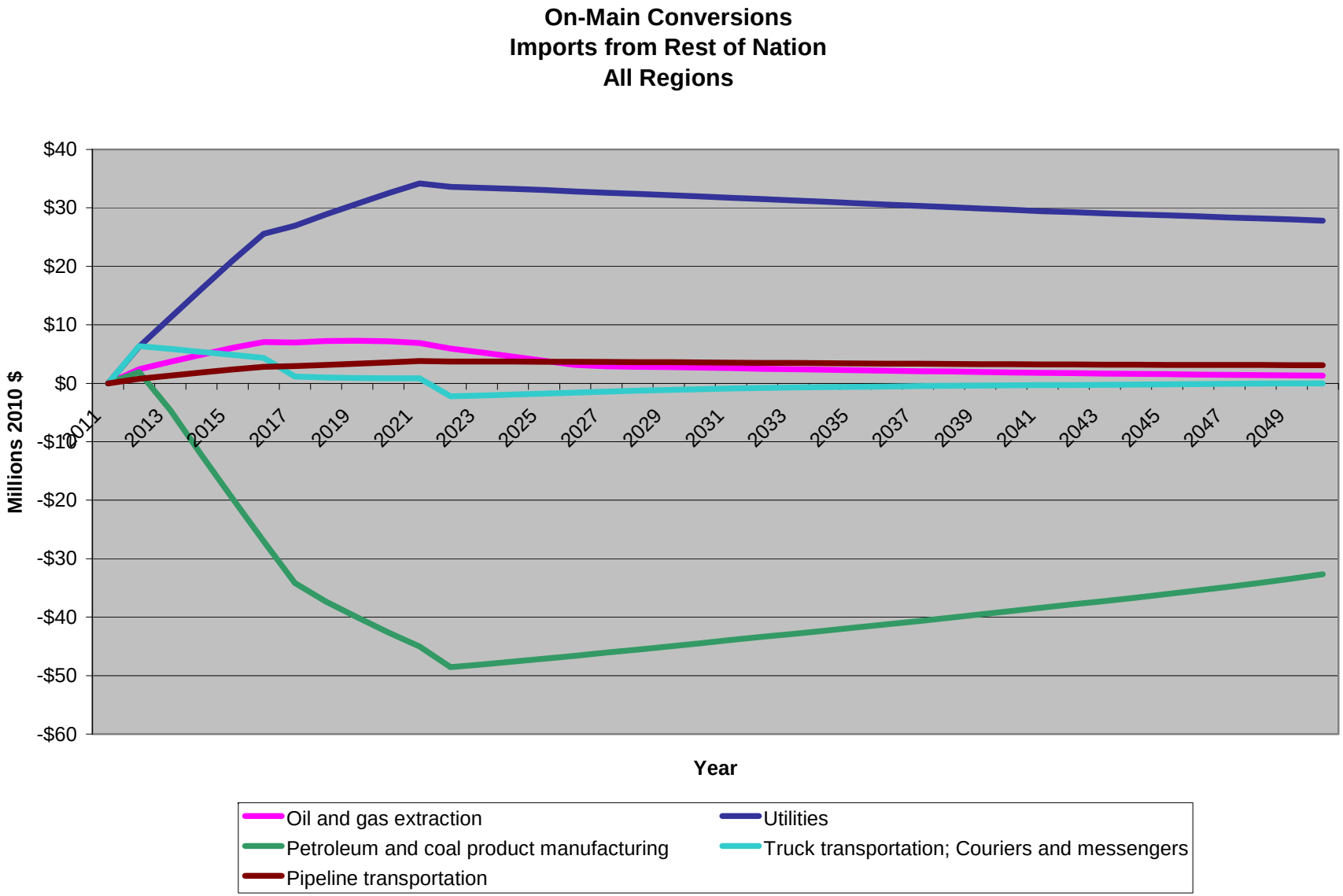


Chart 8: Timepath of Job Creation for Off-Main Conversions

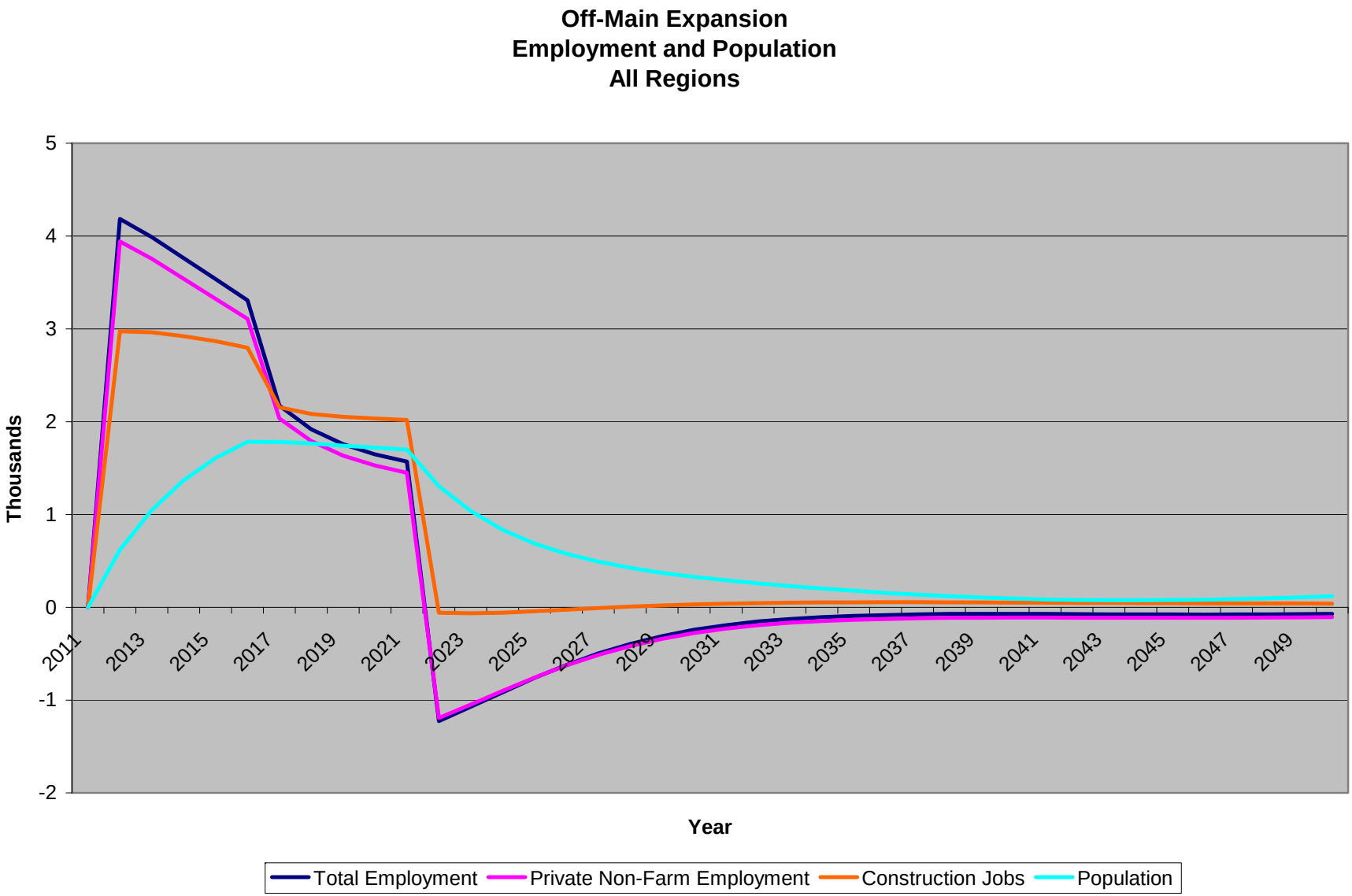


Chart 9: Timepath of Changes in State GDP, Output, Personal Income and Net State Revenue for Off-Main Conversions

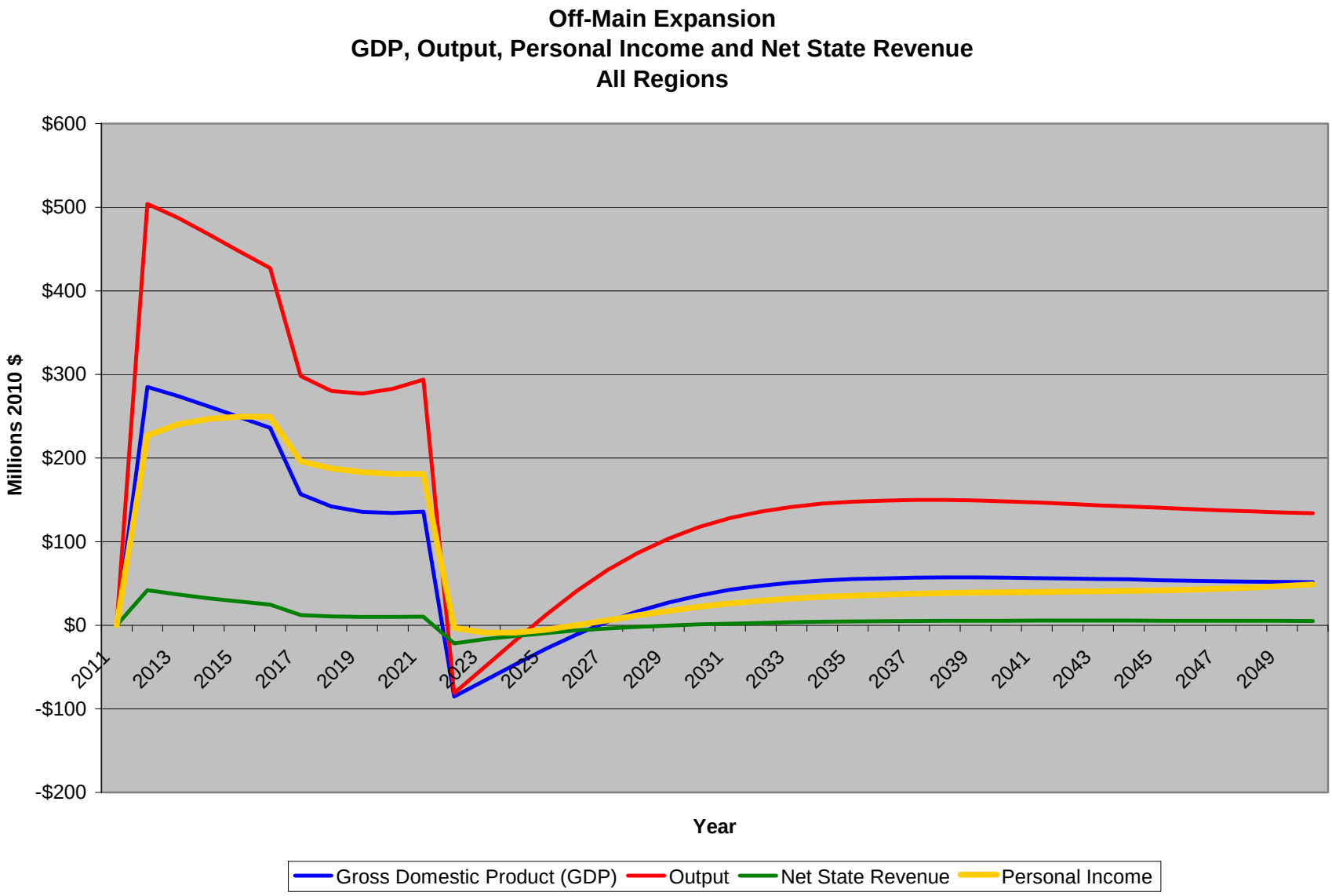
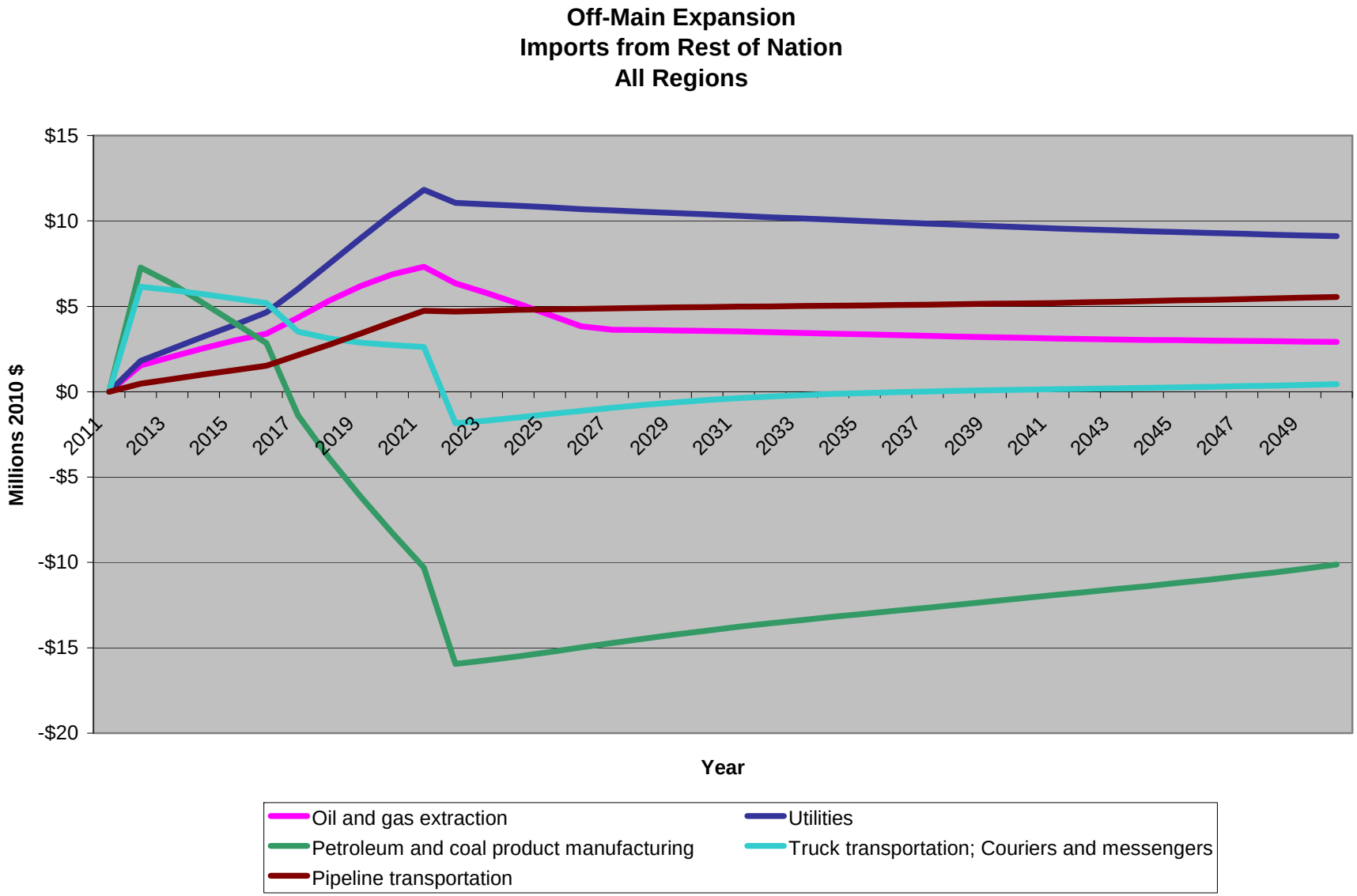


Chart 10: Timepath of Changes in Connecticut's Imports for Off-Main Conversions



Conclusion

The buildout of Connecticut's natural gas infrastructure entails costs and benefits for homeowners and business owners. There is clearly a ten-year period of significant construction and changeover from oil to natural gas space and water heating. The largest increases in jobs, taxes and state gross domestic product occur from 2012 through 2021. From 2022 through 2050, the costs and benefits continue but at a lower level than during the first ten years. Table 8 summarizes these results as annual average changes with respect to the baseline or no build forecast of the Connecticut economy.

There is no adverse impact on the state as we assume the utilities, homeowners and business owners pay for the on-main connections and off-main extensions into areas not previously served. Connecticut will have cleaner air, a lower carbon footprint and its businesses and homeowners will have lower production costs on the one hand and increased household consumption on the other. If the United States can tap further into its natural gas resources, conversion from oil to natural gas may in addition reduce our imports of oil and improve the nation's trade balance.

Appendix A: The REMI Model

The Connecticut REMI model is a dynamic, multi-sector, regional model developed and maintained for the Connecticut Center for Economic Analysis by Regional Economic Models, Inc. of Amherst, Massachusetts. This model provides detail on all eight counties in the State of Connecticut and any combination of these counties. The REMI model includes all of the major inter-industry linkages among 466 private industries, aggregated into 67 major industrial sectors. With the addition of farming and three public sectors (state and local government, civilian federal government, and military), there are 70 sectors represented in the model for the eight counties.[♣]

The REMI model is based on a national *input-output* (I/O) model that the U.S. Department of Commerce (DoC) developed and continues to maintain. Modern input-output models are largely the result of groundbreaking research by Nobel laureate Wassily Leontief. Such models focus on the inter-relationships between industries and provide information about how changes in specific variables—whether economic variables such as employment or prices in a certain industry or other variables like population – affect factor markets, intermediate goods production, and final goods production and consumption.

The REMI Connecticut model takes the U.S. I/O "table" results and scales them according to traditional regional relationships and current conditions, allowing the relationships to adapt at reasonable rates to changing conditions. Listed below are some salient structural characteristics of the REMI model:

- REMI determines consumption on an industry-by-industry basis, and models real disposable income in Keynesian fashion, that is, with prices fixed in the short run and GDP (Gross Domestic Product) determined solely by aggregate demand.
- The demand for labor, capital, fuel, and intermediate inputs per unit of output depends on relative prices of inputs. Changes in relative prices cause producers to substitute cheaper inputs for relatively more expensive inputs.

[♣] The seminal reference is George I. Treyz (1993), Regional Economic Modeling: A Systematic Approach to Economic Forecasting and Policy Analysis, Kluwer Academic Publishers, Boston.

- Supply of and demand for labor in a sector determine the wage level, and these characteristics are factored by regional differences. The supply of labor depends on the size of the population and the size of the workforce.
- Migration—that affects population size—depends on real after-tax wages as well as employment opportunities and amenity value in a region relative to other areas.
- Wages and other measures of prices and productivity determine the cost of doing business. Changes in the cost of doing business will affect profits and/or prices in a given industry. When the change in the cost of doing business is specific to a region, the share of the local and U.S. market supplied by local firms is also affected. Market shares and demand determine local output.
- "Imports" and "exports" between states are related to relative prices and relative production costs.
- Property income depends only on population and its distribution adjusted for traditional regional differences, *not* on market conditions or building rates relative to business activity.
- Estimates of transfer payments depend on unemployment details of the previous period, and total government expenditures are proportional to population size.
- Federal military and civilian employment is exogenous and maintained at a *fixed* share of the corresponding total U.S. values, unless specifically altered in the analysis.
- Because each variable in the REMI model is related, a change in one variable affects many others. For example, if wages in a certain sector rise, the relative prices of inputs change and may cause the producer to substitute capital for labor. This changes demand for inputs, which affects employment, wages, and other variables in those industries. Changes in employment and wages affect migration and the population level that in turn affect other employment variables. Such chain-reactions continue in time across all sectors in the model. Depending on the analysis performed, the nature of the chain of events cascading through the model economy can be as informative for the policymaker as the final aggregate results. Because REMI generates extensive sectoral detail, it is possible for experienced economists in this field to discern the dominant causal linkages involved in the results.

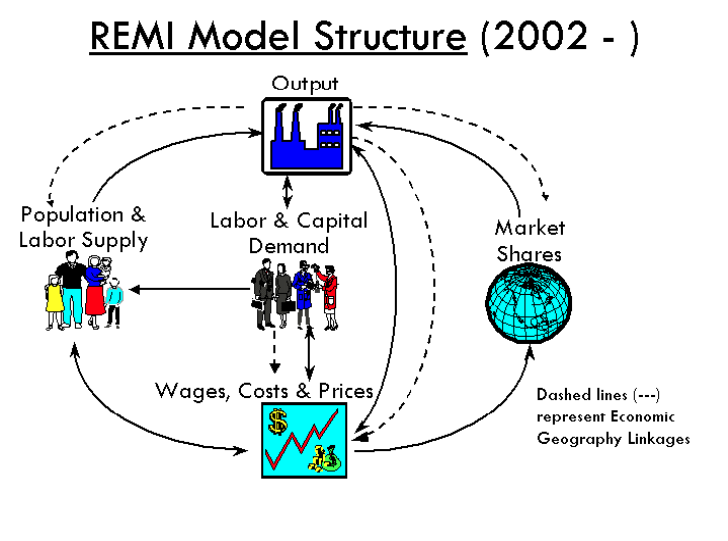
The REMI model is a structural model, meaning that it clearly includes cause-and-effect relationships. The model shares two key underlying assumptions with mainstream economic theory: *households maximize utility* and *producers maximize profits*. In the model, businesses produce goods to sell to other firms, consumers, investors, governments and purchasers outside the region. The output is produced using labor, capital, fuel and intermediate inputs. The demand for labor, capital and fuel per unit output depends on their relative costs, because an increase in the price of one of these inputs leads to substitution away from that input to other inputs. The supply of labor in the model depends on the number of people in the population and the proportion of those people who participate in the labor force. Economic migration affects population size and its growth rate. People move into an area if the real after-tax wage rates or the likelihood of being employed increases in a region.

Supply of and demand for labor in the model determine the real wage rate. These wage rates, along with other prices and productivity, determine the cost of doing business for each industry in the model. An increase in the cost of doing business causes either an increase in price or a cut in profits, depending on the market supplied by local firms. This market share combined with the demand described above determines the amount of local output. The model has many other feedbacks. For example, changes in wages and employment impact income and consumption, while economic expansion changes investment and population growth impacts government spending.

Model Overview

Figure A-1.1 is a pictorial representation of the model. The Output block shows a factory that sells to all the sectors of final demand as well as to other industries. The Labor and Capital Demand block shows how labor and capital requirements depend on both output and their relative costs. Population and Labor Supply are shown as contributing to demand and to wage determination in the product and labor market. The feedback from this market shows that economic migrants respond to labor market conditions. Demand and supply interact in the Wage, Price and Profit block. Once prices and profits are established, they determine market shares, which along with components of demand, determine output.

Figure A-1.1



The REMI model brings together the above elements to determine the value of each of the variables in the model for each year in the baseline forecasts. The model includes each inter-industry relationship that is in an input-output model in the Output block, but goes well beyond the input-output model by including the relationships in all of the other blocks shown in Figure A-1.1.

In order to broaden the model in this way, it is necessary to estimate key relationships econometrically. This is accomplished by using extensive data sets covering all areas of the country. These large data sets and two decades of research effort have enabled REMI to simultaneously maintain a theoretically sound model structure and build a model based on all the relevant data available. The model has strong dynamic properties, which means that it forecasts not only what will happen, but also when it will happen. This results in long-term predictions that have general equilibrium properties. This means that the long-term properties of general equilibrium models are preserved without sacrificing the accuracy of event timing predictions and without simply taking elasticity estimates from secondary sources.

Understanding the Model

In order to understand how the model works, it is critical to know how the key variables in the model interact with one another and how policy changes are introduced into the model. To introduce a policy change, one begins by formulating a policy question. Next, select a baseline forecast that uses the baseline assumptions about the external policy variables and then generate an alternative forecast using an external variable set that includes changes in the external values, which are affected by the policy issue.

Figure A-1.2

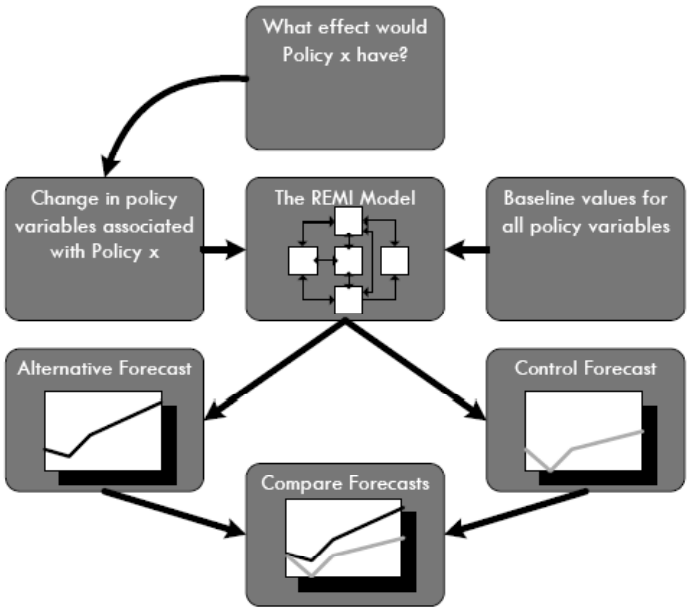


Figure A-1.2 shows how this process would work for a policy change called Policy X. In order to understand the major elements in the model and their interactions, subsequent sections examine the various blocks and their important variable types, along with their relationships to each other and to other variables in the other blocks. The only variables discussed are those that interact with each other in the model. Variables determined outside of the model include:

- Variables determined in the U.S. and world economy (e.g., demand for computers).
- Variables that may change and affect the local area, but over which the local area has no control (e.g., an increase in international migration).
- Variables that are under control of local policy (e.g., local tax rates).

For simplicity, the last two categories are called policy variables. Changes in these variables are automatically entered directly into the appropriate place in the model structure. Therefore, the diagram showing the model structure also serves as a guide to the organization of the policy variables (see Figure A-1.3).

Output Block

The Output Block variables are:

- State and Local Government Spending
- Investment
- Exports
- Consumption
- Real Disposable Income

These variables interact with each other to determine output and depend on variable values determined in other blocks as follows:

Variables in the Output Block	**Variables Outside of the Output Block that are Included in its Determinants**
State and Local Government Spending	Population
Investment	Optimal Capital Stock (also the actual capital stock)
Output	Share of Local Market (The proportion of local demand supplied locally, called the Regional Purchase Coefficient)
Exports	The Regional Share of Interregional and International Trade

Real Disposable Income	Employment, Wage Rates and the Consumer Expenditure Price Index

Labor and Capital Demand Block

The Labor and Capital Demand block has three types of key variables:

- Employment - determined by the labor/output ratio and the output in each industry, determined in the Output block.
- Optimal Capital Stock - depends on relative labor, capital and fuel costs and the amount of employment.
- Labor/Output Ratio - depends on relative labor, capital and fuel costs.

Simply put, if the cost of labor increases relative to the cost of capital, the labor per unit of output falls and the capital per unit of labor increases.

Population and Labor Supply Block

The model predicts population for 600 cohorts segmented by age, ethnicity and gender. This block also calculates the demographic processes - births, deaths and aging. The model deals with different population sectors as follows:

- Retired Migrants are based on past patterns for each age cohort 65 and over.
- International migrants follow past regional distributions by country of origin.
- Military and college populations are treated as special populations that do not follow normal demographic processes.
- Economic migrants are those who are sensitive to changes in quality of life and relative economic conditions in the regional economies. The economic variables that change economic migration are employment opportunity and real after-tax wage rates.

This block allows the determination of the size of the labor force by predicting the labor force participation rates for age, ethnicity and gender cohorts, which are then applied to their respective cohorts and summed. The key variables that change participation rates within the model are the ratio of employment to the relevant population (labor market tightness) and the real after-tax wage rates.

Wage, Price and Profit Block

Variables contained within the Wage, Price and Profit block are:

- Employment Opportunity
- Wage Rate
- Production Costs
- Housing Price
- Consumer Price Deflator
- Real Wage Rate
- Industry Sales Price
- Profitability

The wage rate is determined by employment opportunity and changes in employment demand by occupation for occupations that require lengthy training. The housing price increases when population density increases. The Consumer Expenditure Price Index is based on relative commodity prices, weighted by their share of U.S. nominal personal consumption expenditures. The model uses the price index to calculate the real after-tax wage rate for potential migrants that includes housing price directly, while the price index used to deflate local income uses the local sales price of construction. Wage rates affect production costs, as well as other costs, and they in turn determine profitability or sales prices, depending on whether the type of industry involved serves mainly local or external markets. For example, a cost increase for all local grocery stores results in an increase in their prices, while an increase in costs for a motor vehicle factory reduces its profitability of production at that facility but may not increase their prices worldwide.

Market Shares Block

The Market Shares Block consists of:

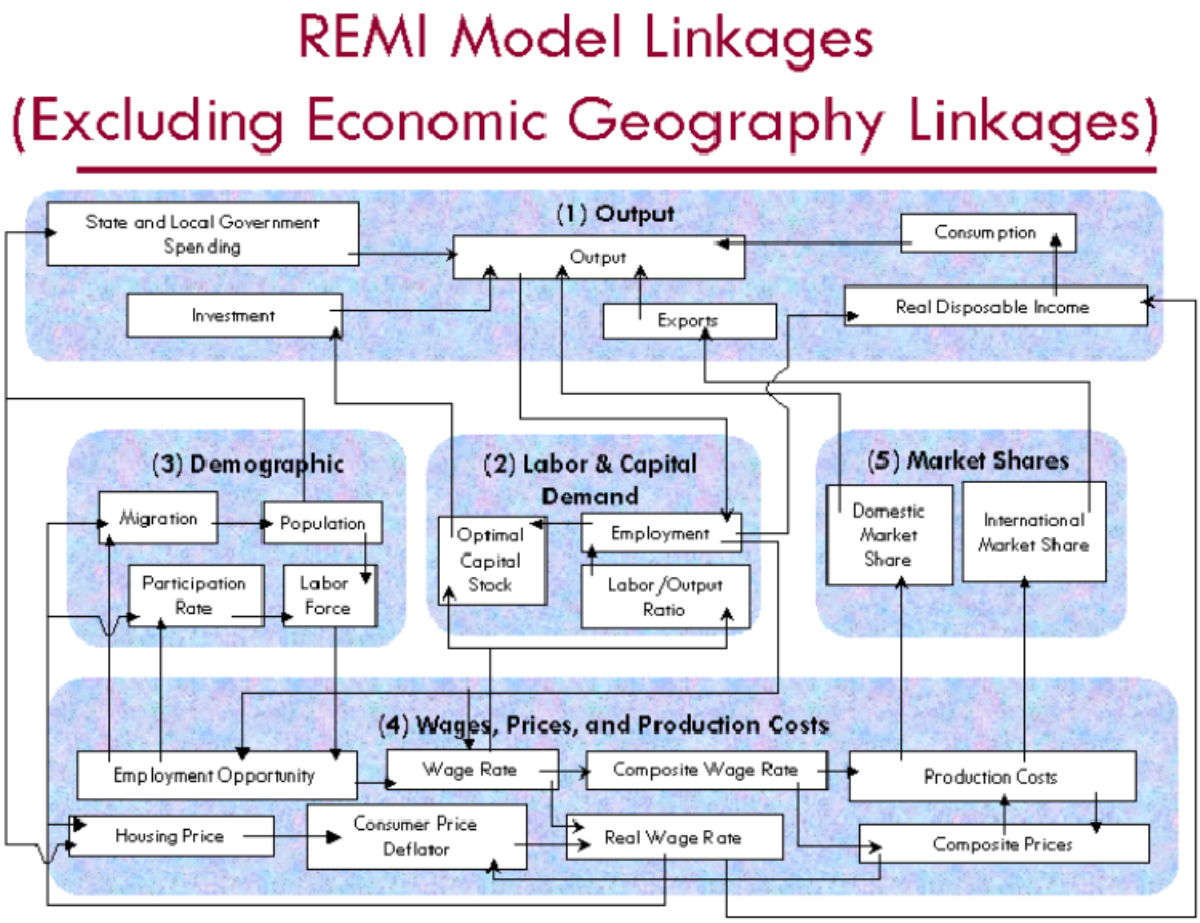
- Share of Local Market
- Share of External Market

An increase in prices leads to some substitution away from local suppliers toward external suppliers. In addition, a reduction in profitability for local factories leads to less expansion of these factories relative to those located in areas where profits have not decreased. These responses occur because the U.S. is a relatively open economy where firms can move to the area that is most advantageous for their business.

The Complete Model

Figure A-1.3 illustrates the entire model and its components and linkages. This diagram is helpful in understanding the complex relationships shared by variables within the various blocks discussed above, as well as their relationships to variables in other blocks.

Figure A-1.3


REMI Model Linkages
(Excluding Economic Geography Linkages)
(1) Output
State and Local Government Spending
Output
Consumption
Investment
Exports
Real Disposable Income
(3) Demographic
Migration
Population
Participation Rate
Labor Force
(2) Labor & Capital Demand
Optimal Capital Stock
Employment
Labor/Output Ratio
(5) Market Shares
Domestic Market Share
International Market Share
(4) Wages, Prices, and Production Costs
Employment Opportunity
Wage Rate
Composite Wage Rate
Production Costs
Housing Price
Consumer Price Deflator
Real Wage Rate
Composite Prices