The Economic Impacts of Clean Power

Discussion of Arkolakis and Walsh (2024)

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SUMMARY AND DISCUSSION OUTLINE

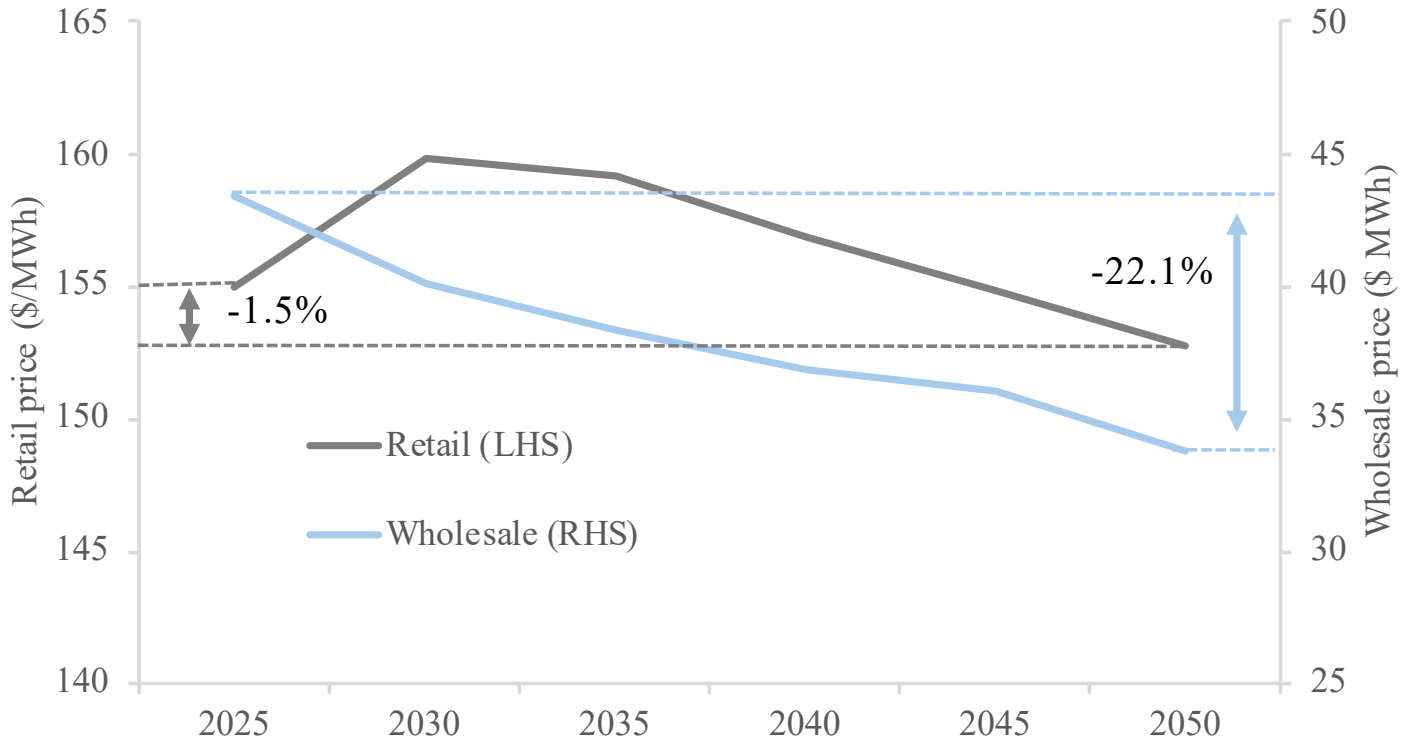
Summary of Arkolakis and Walsh:

- Fall in battery and solar costs drive 20-80% reductions in wholesale electricity prices
- Lower electricity prices raise wages by 2-3% nationwide and may significantly raise TFP growth

Main comment: Electricity price declines likely to be more modest:

1. Technology cost assumptions
2. System v. levelized cost of electricity
3. Recent electricity price trends

ENERGY SYSTEMS MODELING INDICATE MODEST PRICE DECLINES



- Wholesale prices decline by 2040 is 15%, by 2050 is 22%
- Arkolakis and Walsh estimate decline of 37% by 2040

Capital and levelized cost expected to fall sharply

Capital cost

	$/KW			% change from 2023	
	2023	2040	2050	2040	2050
Natural gas	1522	1309	1206	-14	-21
Solar PV	1611	825	683	-49	-58
Solar PV + 4 hour battery	2590	1400	1154	-46	-55

Levelized cost of electricity (LCOE)

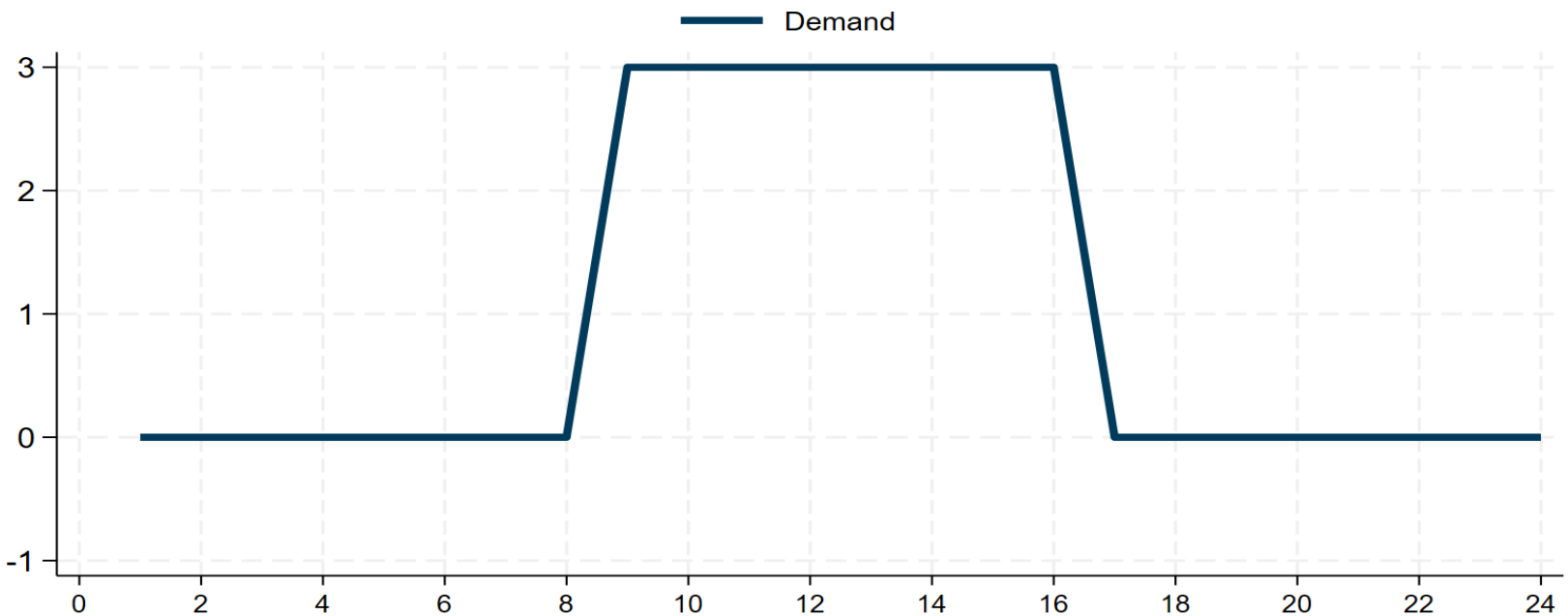
	$/MWh			% change from 2023		Capacity factor
	2023	2040	2050	2040	2050	
Natural gas	44	41	40	-6	-10	0.66
Solar PV	43	23	20	-47	-55	0.33
Solar PV + 4 hour battery	93	55	47	-41	-49	0.33 / 0.16

$$P_i^k = \sum_{t=1}^{T} \frac{P_i^e \theta_i - \phi_i - F_i \theta_i}{(1+r)^t}$$

$$\Rightarrow P_i^e = F_i + \theta_i{}^{-1} \left(\phi_i + P_i^k C(r) \right)$$

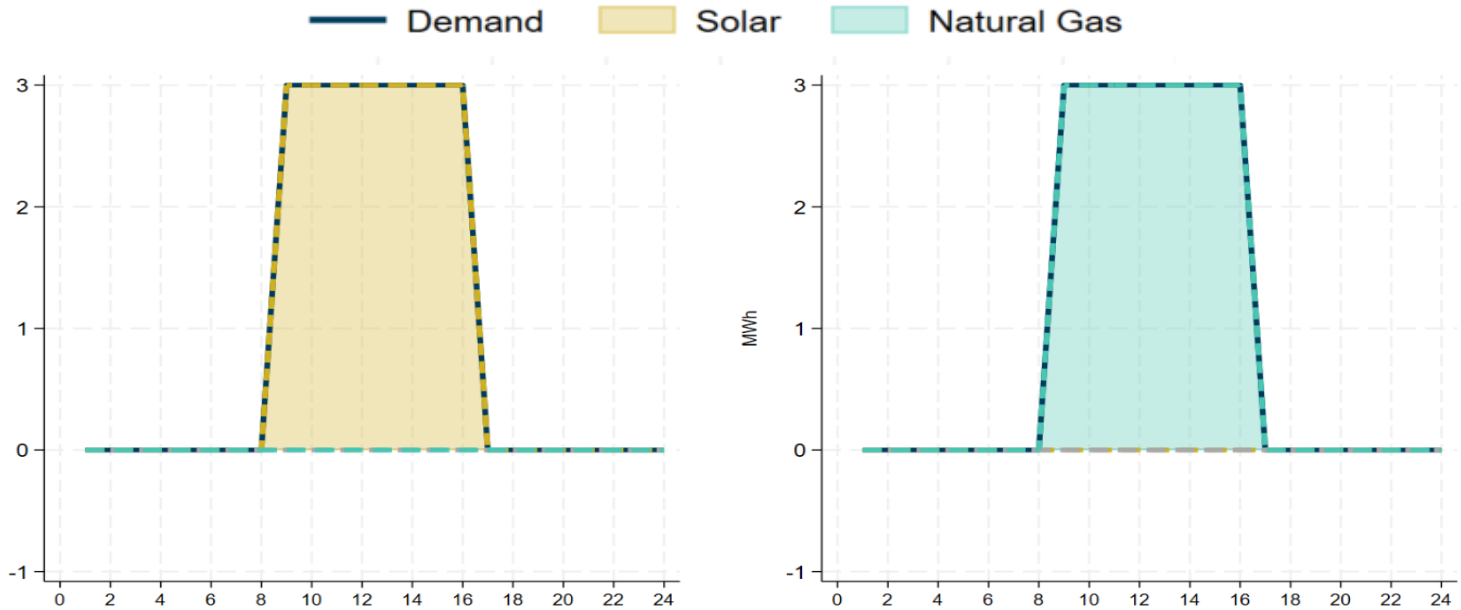
System cost of electricity

Solar scenario



System cost = LCOE

Solar scenario

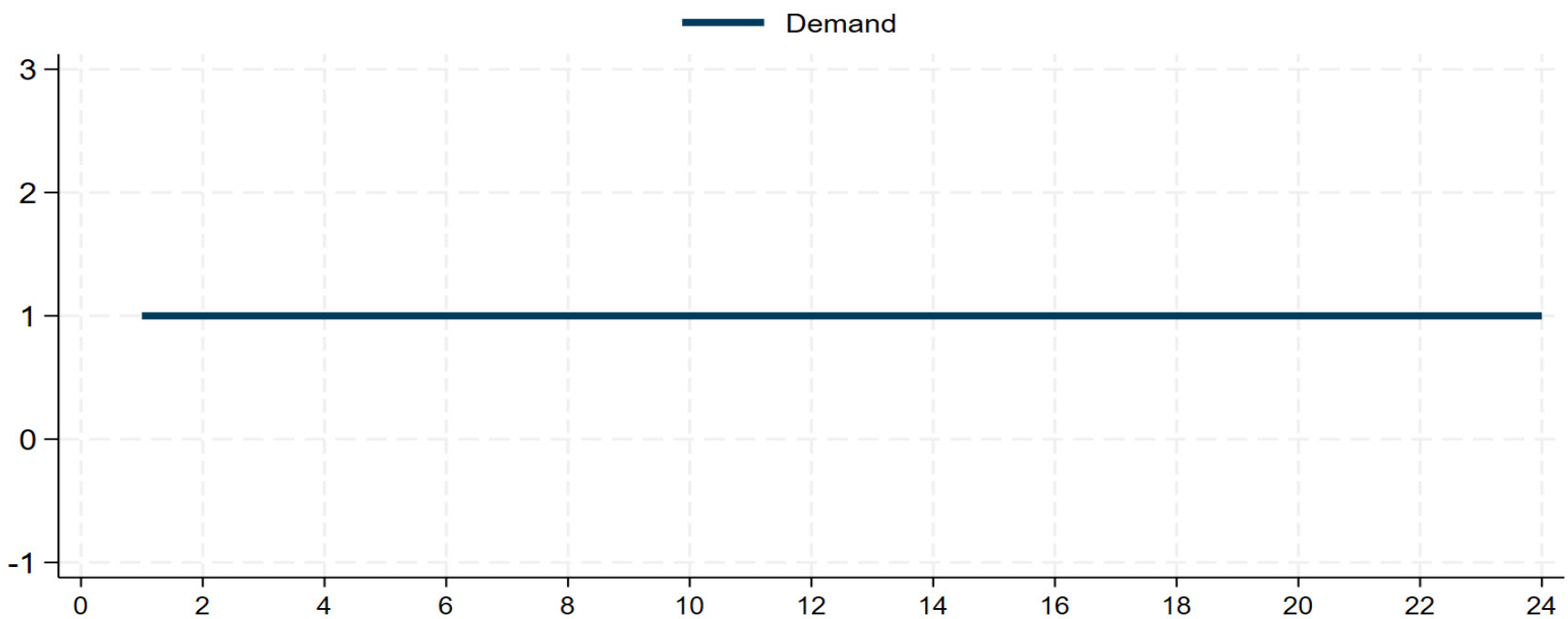


	System cost of electricity ($/MWh)			Capacity factor
	2023	2040	2050	
Natural gas only	65	60	57	0.33
Solar only	43	23	20	0.33

$$P_{NG}^{k} = \sum_{t=1}^{T} \frac{P_e \tilde{\theta}_{NG} - \phi_i - F_{NG} \tilde{\theta}_{NG}}{(1+r)^t}$$

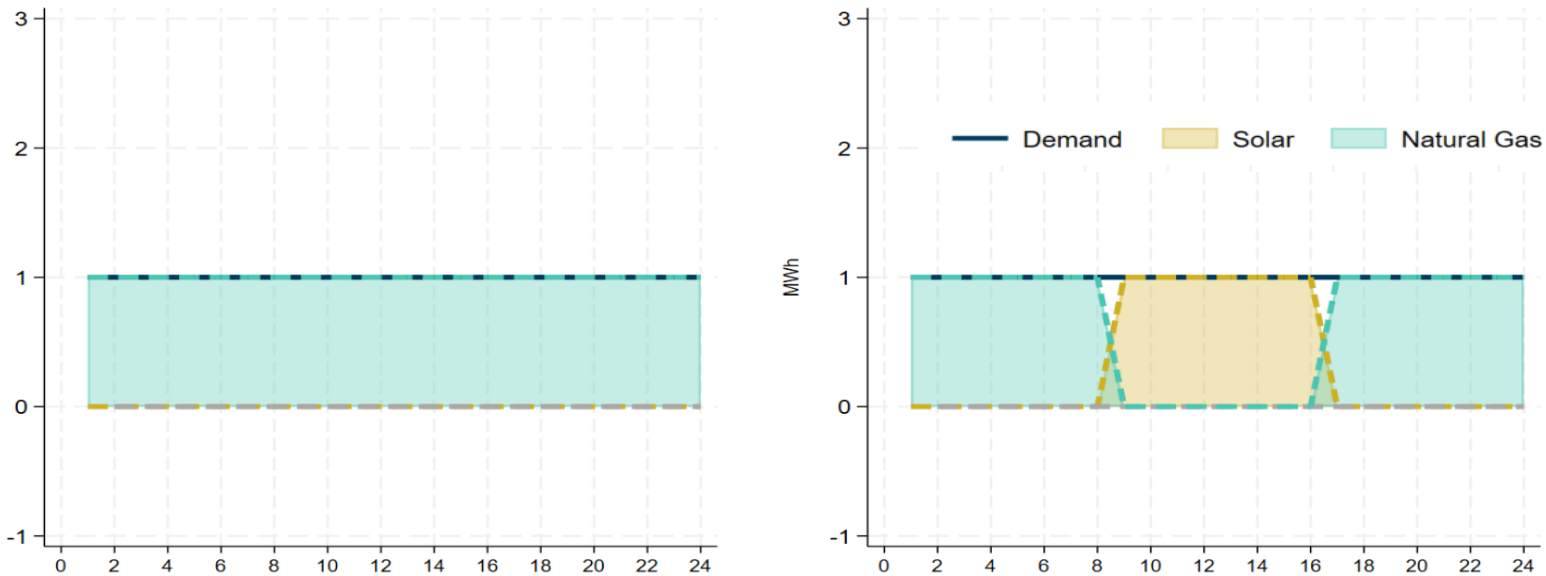
System cost of electricity

Natural gas scenario



System cost as weighted average

Natural gas scenario

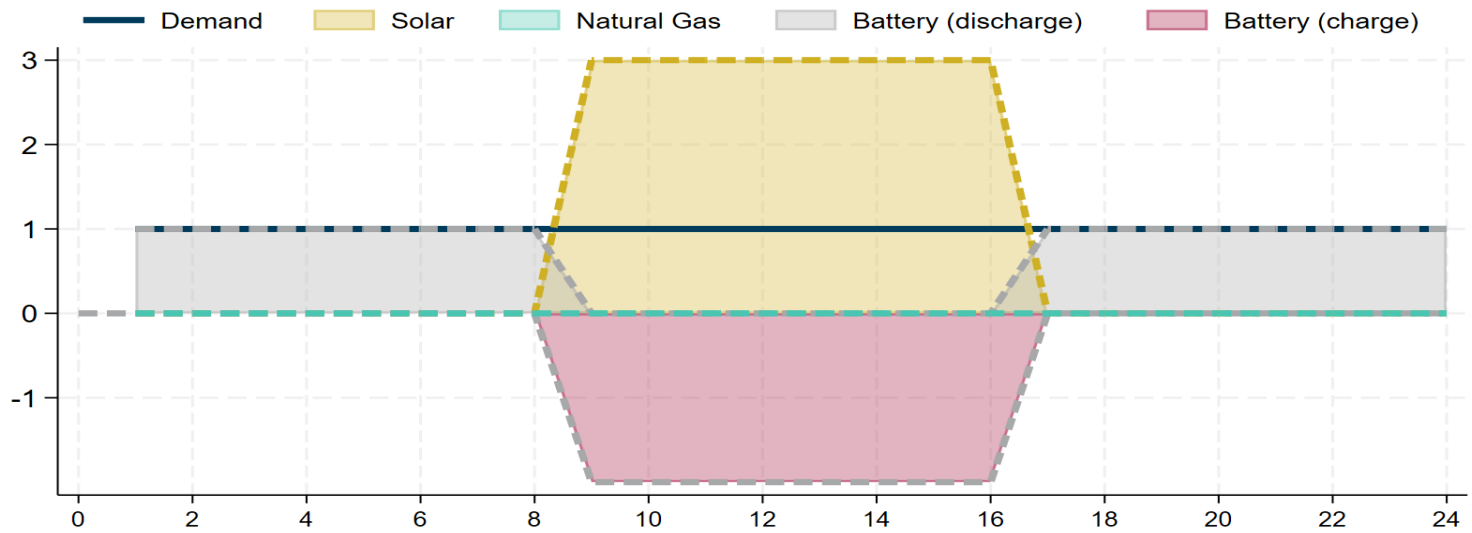


$$P_e = \omega_{NG} P_{e,NG} + (1 - \omega_{NG})\, P_{e,solar}$$

- ω_{NG} is the share of electricity generation from natural gas

System cost with storage

Natural gas scenario

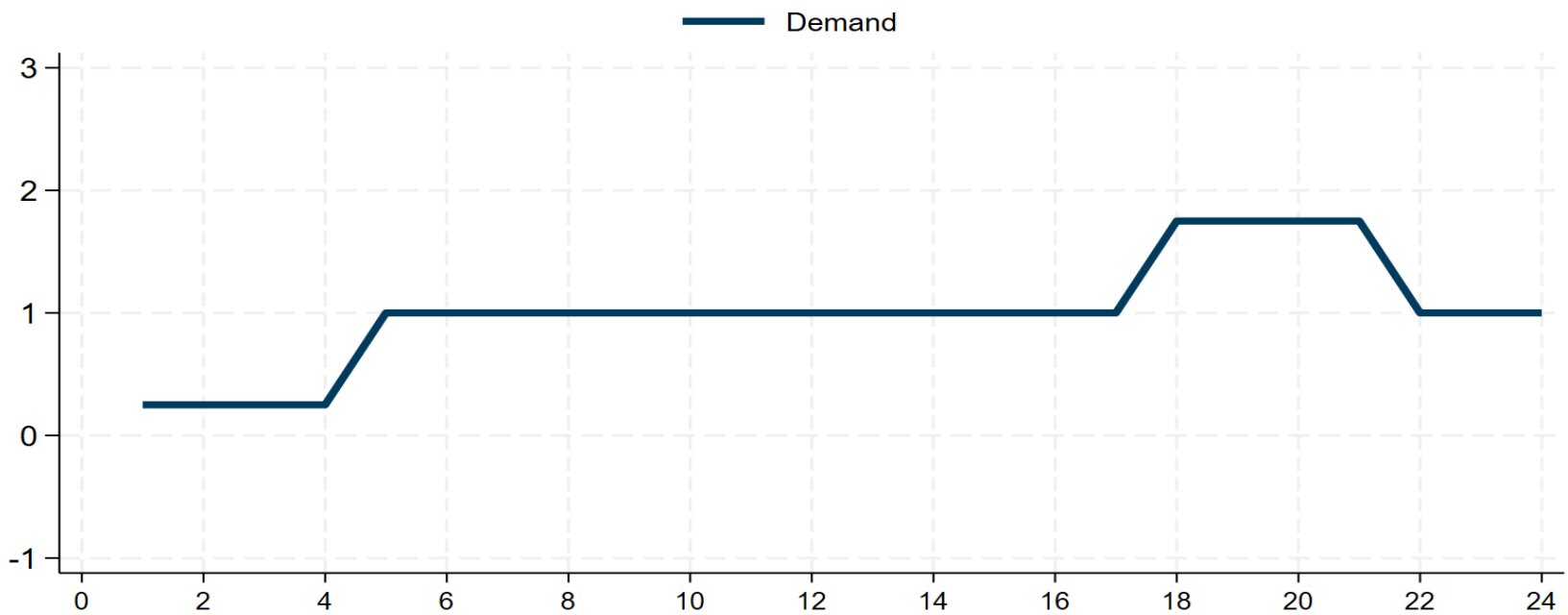


	System cost of electricity ($/MWh)			Capacity factor
	2023	2040	2050	
Natural gas only	37	35	34	1.00
Solar + natural gas	44	35	33	0.33 / 0.66
Solar + storage	96	52	43	0.33 / 0.33

$$\sum_i P_i^k K_i = \sum_i \sum_{t=1}^{T} \frac{\left(P_e \tilde{\theta}_i - \phi_i - F_i \tilde{\theta}_i\right) K_i}{(1+r)^t}$$

System cost ≠ LCOE

Realistic scenario



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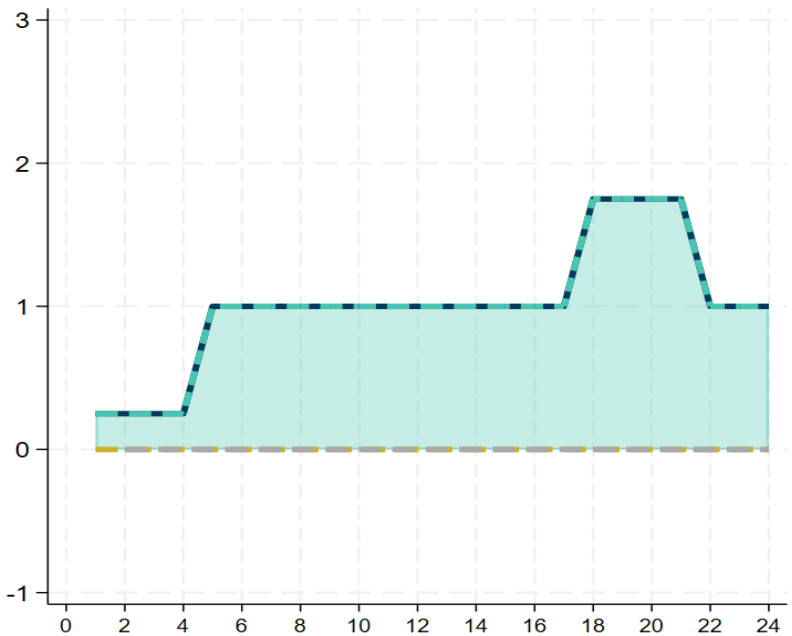
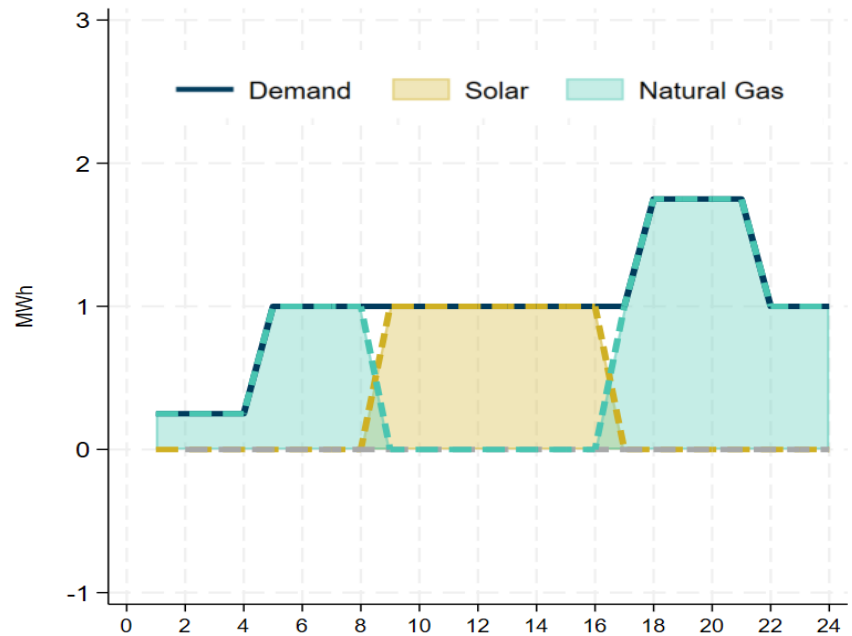
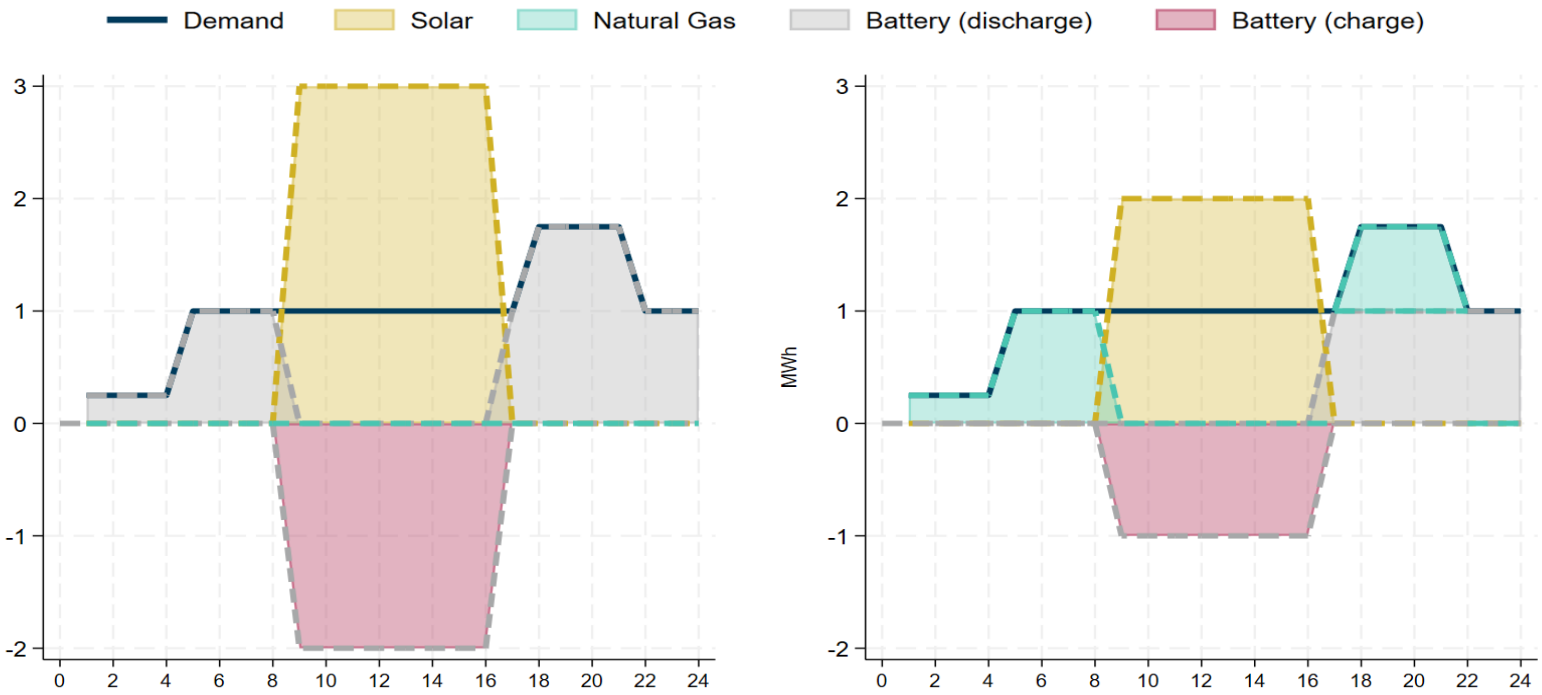
Realistic scenario





System cost ≠ LCOE

Realistic scenario



	System cost of electricity ($/MWh)			Capacity factor
	2023	2040	2050	
Natural gas only	47	44	42	1.00
Solar + natural gas	54	44	42	0.33 / 0.66
Solar + storage only	96	52	43	0.33 / 0.33
Solar + storage + natural gas	73	47	41	0.33 / 0.33 / 0.33

TECHNOLOGY COSTS NOT DECISIVE FOR ELECTRICITY PRICES

	Level			% change	
	1999-03	2004-08	2019-23	20-year	15-year
Electricity cost					
Residential cost (2023 cents/KWh)	13.9	14.8	15.5	12	5
Industry cost (2023 cents/KWh)	7.9	8.9	8.1	3	-9
PPI: electricity to industry (2023 = 100)	89	92	95	7	3
PPI: electricity to commerce (2023 = 100)	75	82	95	27	16
Fuel cost					
Coal (2023 $/MMBtu)	2.04	2.45	2.35	15	-4
Natural gas (2023 $/MMBtu)	6.37	10.87	3.78	-41	-65
Capital cost					
10-year Treasury rate	5.1	4.3	2.3	-55	-47
Price index for turbines (2017 = 100)	112	105	98	-12	-7
Price index for electric power structures (2017 = 100)	89	101	94	6	-6

- Real electricity prices have generally risen in past 15-20 years
- Increase in electricity prices despite large decreases in cost of natural gas, interest rates and equipment cost

TAKING STOCK

- Arkolakis and Walsh (2024) solar and battery cost assumptions optimistic but comparable to energy systems inputs
- Systemwide electricity costs can differ markedly from levelized cost estimates
  - Ensuring adequate dispatchable capacity remains challenging with renewables and battery storage
  - True irrespective of a zero emissions target
- Electricity prices have risen recently despite markedly lower fuel and capital costs
- Wholesale price reductions likely, but more modest (10-20% range)

Macroeconomic Impacts

- Wages gains modest due to low share of electricity in aggregate production:
  - Aggregate production: $F(K, E, N) = K^{\alpha} E^{\eta} N^{1-\alpha-\eta}$
  - With an electricity share of 1.1%, 20-80% electricity price decline implies 0.4-1.5% rise in wages
- Conditional on price declines, are welfare gains understated?
  - Direct household consumption is more than 1/3 of electricity use
  - Spatial reallocation of industry within the US and from rest-of-world may be significant
  - Potential productivity growth impact dwarf the wage impacts