Does the mandatory electricity savings target really prompt Taiwan's petrochemical industry to save more?

Industrial Technology Research Institute
Wayne Lin

ABSTRACT

In 2015, the government of Taiwan executed a regulation that requires large energy users with contract capacities higher than 800 kW to save at least 1% of electricity consumption annually. This research examines whether the regulation has prompted large energy users in the petrochemical industry to save more electricity than they did before the execution of the regulation.

This research analyses the energy intensity and savings data from twenty types of petrochemical manufacturers. The result shows that in the case of Vinyl chloride, Styrene, Acrylonitrile, Polyethylene, Polyvinyl chloride, Polystyrene, ABS resins and Thermal plastic elastomer, the savings rates and improvement of the electricity intensity both improved after the regulation took effect. Second, in the case of Ethylene, Ethylene glycol and Epichlorohydrin, savings rates improved, but electric intensity declined little to none between 2014 and 2015. Finally in the case of Pure Terephthalic acid, Methyl methacrylate, Phthalic anhydride and Polypropylene, savings rates improved, but electric intensity increased following the regulation.

Producers of Ethylene, Ethylene glycol and Pure Terephthalic acid explained that the negative impacts of some technical factors and business issues on energy consumption offset the effect of energy conservation measures. Because of the lack of quantified data, this information is unable to verify that the energy intensity without negative impacts would improve more after the regulation took effect.

1. Background

In Taiwan, the Energy Administration Act authorizes the government to execute energy conservation regulations. The energy audit regulation requires large energy users with contract capacities higher than 800 kW to establish their own energy audit systems, set objectives for energy conservation, and report energy consumption data to the Bureau of Energy. In 2015, a further regulation required large energy users to save at least 1% of electricity consumption annually.

According to the energy balance statistics, the petrochemical industry in Taiwan consumed electricity 17,380 GWh in 2015, accounting for 13% of the entire industrial sector's consumption. Its share is second only to the electronic parts industry, which is responsible for 23% of industrial electricity consumption.

This study examines whether the mandatory 1% electricity savings target mandated in 2015 prompted Taiwan's petrochemical industry to actually improve its energy performance. Section 2 identifies large energy users who produce major petrochemicals, and analyzes their electricity consumption and savings data. Then this study examines whether the electricity intensity of the major petrochemical facilities follows the trend of power savings. Section 3

summarizes the analysis result and the information from the interviews with large energy users. Conclusions are presented in section 4.

2. Electricity consumption data

The analysis is performed in three steps. First, major petrochemical materials producers are identified (Section 2.1). Then, their electricity consumption and savings data are analyzed (Section 2.2). In the third step, the electricity intensity of their products are compared with their electricity savings rate (Section 2.3).

2.1. Identification of major petrochemicals producers

This study considers 20 kinds of petrochemicals, and identifies those large energy users that are required to report energy consumption data to the government. Table 1 presents the number of these plants and their total capacity in April 2015.

Because only one aromatics producer's energy consumption data is available, aromatics is not included in this study. As to Styrene monomer, Polyethylene, Polystyrene, Phenol and Bisphenol A, some producers do not completely report their energy consumption data to the government, therefore the number of plants and total capacity is not exhaustive.

Table 1. Number of plants and capacity of major petrochemicals in 2015

Product	Number of plants	Capacity 1,000 metric tons annual
Ethylene	5 plants	4005
Vinyl chloride (VCM)	4 plants	2000
Styrene (SM)	3 plants	1476
Acrylonitrile (AN)	2 plants	504
Pure Terephthalic acid (PTA)	4 plants	3400
Ethylene glycol (EG)	3 plants	2100
Methyl methacrylate (MMA)	2 plants	203
Epichlorohydrin (ECH)	2 plants	172
Phthalic anhydride (PA)	2 plants	276
Polyethylene (PE)	4 plants	884
Polypropylene (PP)	3 plants	1310
Polyvinyl chloride (PVC)	6 plants	1735
Polystyrene (PS)	5 plants	827
ABS Resins	5 plants	1980
Polycarbonate (PC)	2 plants	340
Thermal plastic elastomer (TPE)	4 plants	275
Butadiene rubber (BR)	2 plants	165
Styrene-butadiene rubber (SBR)	2 plants	120
Phenol	2 plants	780
Bisphenol A	2 plants	370

Source: Petrochemical Industry Association of Taiwan, 2015.

2.2. Electricity consumption and savings

This study targets 57 plants that produce petrochemicals listed on Table1. Eight of them produce multiple products, some products are petrochemicals considered in this study and some are downstream products.

Based on the reporting data from large energy users, Table 2 summarizes the annual electricity consumption and savings data totals of target plants between 2010 and 2015.

Total electricity consumption of these 57 plants declined 19% during the period from 2010 to 2015. Their reported energy savings (GWh) caused by their energy conservation measures almost tripled during this period. As a result, the electricity savings rate of these plants increase from 0.5% in 2010 to 1.6% in 2015, despite the dip in 2014.

Table 2. Electricity consumption and savings of target producers

	2010	2011	2012	2013	2014	2015
Power consumption (GWh)	11,587	10,654	10,560	9,128	8,569	9,371
Power saving (GWh)	53	46	106	124	50	157
Saving rate*	0.5%	0.4%	1.0%	1.3%	0.6%	1.6%

* Savings rate is calculated by power savings divided by the sum of savings and consumption. *Source:* Energy Audit Database, Bureau of Energy, Taiwan.

2.3. Electricity intensity of petrochemical processes

The declining power consumption in major petrochemicals producers may be the result of production decrease or energy conservation measures. Table 3 presents the petrochemical production index of target plants, the base year is 2015. The production of Pure Terephthalic acid dropped 23% in six years, Phthalic anhydride, Polystyrene, Phenol and Bisphenol A declined over 10%. According to the annual report of Petrochemical Industry Association of Taiwan, the production of ABS Resins decreased 10% during the period of 2010-2015. On the other hand, the production of Ethylene and Polyvinyl chloride increased by over 10%. Overall, production increases in certain petrochemicals is balanced by decreases in others.

Table 3. The petrochemical production index

Product	2010	2011	2012	2013	2014	2015	2010-2015 change
Ethylene	81	73	72	81	95	100	23%
Vinyl chloride (VCM)	92	87	93	98	94	100	9%
Styrene (SM)	99	76	94	101	103	100	1%
Acrylonitrile (AN)	97	88	94	97	56	100	3%
Pure Terephthalic acid (PTA)	129	130	114	93	91	100	-23%
Ethylene glycol (EG)	99	90	92	92	99	100	1%

Product	2010	2011	2012	2013	2014	2015	2010-2015 change
Methyl methacrylate (MMA)	108	96	100	101	105	100	-7%
Epichlorohydrin (ECH)	98	93	91	92	96	100	2%
Phthalic anhydride (PA)	111	81	96	90	80	100	-10%
Polyethylene (PE)	101	90	78	95	91	100	-1%
Polypropylene (PP)	108	96	93	107	93	100	-7%
Polyvinyl chloride (PVC)	87	86	92	97	94	100	15%
Polystyrene (PS)	112	113	105	107	89	100	-11%
ABS Resins*			98	99	98	100	2%
Polycarbonate (PC)*			96	101	97	100	4%
Thermal plastic elastomer (TPE)*				96	103	100	4%
Butadiene rubber (BR)*				101	124	100	-1%
Styrene-butadiene rubber (SBR)*				96	106	100	4%
Phenol	134	118	102	107	98	100	-26%
Bisphenol A	119	117	107	104	98	100	-16%

* One plant that produces ABS resins, PC and rubbers modified its energy management system, its data after the year of 2011 and 2012 is more credible. *Source:* Energy Audit Database, Bureau of Energy, Taiwan.

Table 4 shows the power consumption index of petrochemicals processes, which is the annual consumption divided by the consumption in the base year of 2015. Following the production trend, the power consumed in the processes of Pure Terephthalic acid, Phthalic anhydride, Polystyrene, Phenol and Bisphenol A also declined over 10%, and the power consumed in naphtha crackers increased 20%.

Table 4. The electricity consumption index of petrochemicals processes

Product	2010	2011	2012	2013	2014	2015	2010-2015 change
Ethylene	83	80	83	83	96	100	20%
Vinyl chloride (VCM)	96	94	100	99	97	100	4%
Styrene (SM)	97	72	101	102	104	100	3%
Acrylonitrile (AN)	126	124	124	126	65	100	-20%
Pure Terephthalic acid (PTA)	122	128	120	97	88	100	-18%

Product	2010	2011	2012	2013	2014	2015	2010-2015 change
Ethylene glycol (EG)	94	92	96	95	100	100	7%
Methyl methacrylate (MMA)	101	96	104	103	102	100	-1%
Epichlorohydrin (ECH)	103	102	100	96	97	100	-3%
Phthalic anhydride (PA)	116	92	108	101	63	100	-14%
Polyethylene (PE)	98	94	85	96	95	100	2%
Polypropylene (PP)	104	92	96	103	91	100	-4%
Polyvinyl chloride (PVC)	96	94	97	102	98	100	4%
Polystyrene (PS)	114	108	104	102	89	100	-12%
ABS Resins*			107	101	103	100	-6%
Polycarbonate (PC)*			97	98	95	100	3%
Thermal plastic elastomer (TPE)*				88	106	100	13%
Butadiene rubber (BR)*				107	127	100	-6%
Styrene-butadiene rubber (SBR)*				90	100	100	11%
Phenol	115	85	94	88	89	100	-13%
Bisphenol A	112	124	139	114	102	100	-10%

* One plant that produces ABS resins, PC and rubbers modified its energy management system, its data after the year of 2011 and 2012 is more credible. *Source:* Energy Audit Database, Bureau of Energy, Taiwan.

Table 3 and table 4 show that the declining production of some petrochemicals, such as Pure Terephthalic acid and Phenol, drove reductions in power consumption of some target plants. The energy reductions due to declining production of those products is greater than the energy increases due to increasing production of Ethylene, Vinyl chloride, Ethylene glycol and Polyvinyl chloride.

As to the power savings, the electricity intensity (the power consumption per metric ton of production) may explain whether the process efficiencies have significantly improved between 2010-2015. Table 5 presents the electricity intensity index of petrochemical processes, which is the annual intensity divided by the intensity in the base year of 2015. The electricity intensity of Acrylonitrile and Polyvinyl chloride decreased 22% and 9% respectively in six years. Also the electricity intensity of ABS Resins and Butadiene rubber have seen improvement. However, the electricity intensity of other petrochemicals do not show significant improvement.

Table 5. The electricity intensity index of petrochemical processes

Product	2010	2011	2012	2013	2014	2015	2010-2015 change
Ethylene	103	110	115	103	100	100	-3%
Vinyl chloride (VCM)	104	108	107	101	104	100	-4%
Styrene (SM)	99	94	107	101	101	100	2%
Acrylonitrile (AN)	129	141	132	130	116	100	-22%
Pure Terephthalic acid (PTA)	95	98	106	104	96	100	6%
Ethylene glycol (EG)	94	102	105	103	101	100	6%
Methyl methacrylate (MMA)	94	100	105	102	98	100	6%
Epichlorohydrin (ECH)	106	110	109	105	101	100	-5%
Phthalic anhydride (PA)	105	114	113	112	79	100	-5%
Polyethylene (PE)	97	104	110	101	104	100	4%
Polypropylene (PP)	96	96	103	96	99	100	4%
Polyvinyl chloride (PVC)	110	110	105	105	104	100	-9%
Polystyrene (PS)	102	95	99	95	101	100	-2%
ABS Resins*			108	102	105	100	-8%
Polycarbonate (PC)*			101	97	99	100	-1%
Thermal plastic elastomer (TPE)*				92	103	100	9%
Butadiene rubber (BR)*				106	103	100	-6%
Styrene-butadiene rubber (SBR)*				94	94	100	7%
Phenol	86	72	92	82	91	100	16%
Bisphenol A	94	106	129	110	105	100	7%

* One plant that produces ABS resins, PC and rubbers modified its energy management system, its data after the year of 2011 and 2012 is more credible. *Source:* Energy Audit Database, Bureau of Energy, Taiwan.

Table 6 and Table 7 examine year-to-year change of the electricity intensity and the electricity savings rate of petrochemical processes respectively.

Table 6. Year-to-year change of the electricity intensity of petrochemical processes

Product	2010-2011	2011-2012	2012-2013	2013-2014	2014-2015
Ethylene	7.19%	4.32%	-10.61%	-2.33%	-0.33%

Product	2010-2011	2011-2012	2012-2013	2013-2014	2014-2015
Vinyl chloride (VCM)	4.02%	-1.42%	-5.46%	2.38%	-3.39%
Styrene (SM)	-4.15%	13.65%	-5.84%	0.30%	-1.32%
Acrylonitrile (AN)[+]	8.96%	-6.40%	-1.48%		-22.84%
Pure Terephthalic acid (PTA)	3.57%	7.74%	-1.43%	-7.62%	3.93%
Ethylene glycol (EG)	8.48%	2.06%	-1.45%	-2.21%	-0.75%
Methyl methacrylate (MMA)	6.10%	4.96%	-2.57%	-4.25%	2.46%
Epichlorohydrin (ECH)	4.34%	-1.01%	-3.98%	-3.60%	-0.86%
Phthalic anhydride (PA)	8.93%	-1.51%	-0.48%	-29.28%	26.24%
Polyethylene (PE)	7.35%	6.20%	-8.52%	3.72%	-4.28%
Polypropylene (PP)	-0.79%	7.43%	-6.54%	2.80%	1.43%
Polyvinyl chloride (PVC)	-0.45%	-4.54%	0.50%	-0.96%	-4.23%
Polystyrene (PS)	-6.67%	4.08%	-3.77%	5.92%	-0.80%
ABS Resins*			-5.80%	2.86%	-4.76%
Polycarbonate (PC)*			-4.78%	2.01%	1.51%
Thermal plastic elastomer (TPE)*				12.48%	-3.16%
Butadiene rubber (BR)*				-3.31%	-2.71%
Styrene-butadiene rubber (SBR)*				0.32%	6.33%
Phenol	-16.10%	27.40%	-10.32%	9.90%	10.35%
Bisphenol A	13.50%	21.63%	-15.14%	-4.71%	-4.49%

[+] One Acrylonitrile producer did not report energy data in 2014, therefore the electricity intensity of Acrylonitrile in 2015 is compared with that in 2013. * One plant that produces ABS resins, PC and rubbers modified its energy management system, its data after the year of 2011 and 2012 is more credible. *Source:* Energy Audit Database, Bureau of Energy, Taiwan.

Table 7. The electricity savings rate of petrochemical processes

	2010	2011	2012	2013	2014	2015
Ethylene	0.1%	0.2%	4.1%	6.5%	0.3%	1.2%
Vinyl chloride (VCM)	0.6%	0.3%	2.3%	0.1%	0.1%	0.8%
Styrene (SM)	0.0%	0.9%	0.1%	0.1%	3.4%	2.1%
Acrylonitrile (AN)	0.0%	0.2%	1.2%	0.3%	0.6%	1.3%
Pure Terephthalic acid (PTA)	0.4%	0.4%	2.4%	1.8%	1.4%	3.4%
Ethylene glycol (EG)	0.2%	0.2%	0.0%	0.0%	0.1%	1.0%

	2010	2011	2012	2013	2014	2015
Methyl methacrylate (MMA)	1.4%	0.4%	0.4%	0.3%	1.7%	1.0%
Epichlorohydrin (ECH)	6.6%	5.8%	2.6%	5.9%	1.4%	3.2%
Phthalic anhydride (PA)	0.2%	1.3%	0.3%	1.1%	0.2%	0.4%
Polyethylene (PE)	0.1%	0.3%	0.0%	0.1%	0.1%	1.3%
Polypropylene (PP)	0.4%	0.5%	0.2%	0.3%	1.6%	0.7%
Polyvinyl chloride (PVC)	0.1%	0.5%	0.2%	0.7%	0.5%	2.1%
Polystyrene (PS)	1.2%	0.7%	0.0%	0.6%	0.3%	1.5%
ABS Resins	0.2%	0.1%	0.3%	12.3%	0.0%	2.1%
Thermal plastic elastomer (TPE)	1.1%	1.1%	0.5%	4.5%	3.3%	2.0%

Source: Energy Audit Database, Bureau of Energy, Taiwan.

For Vinyl chloride, Styrene, Polyethylene, Polyvinyl chloride, Polystyrene, ABS resins and Thermal plastic elastomer, improvement in the electricity intensity in 2015 are greater than their performance in 2014. Acrylonitrile also performs better in 2015 than in 2013. The increasing savings rates in 2015 in the processes of Vinyl chloride, Acrylonitrile, Polyethylene, Polyvinyl chloride, Polystyrene and ABS resins correspond with improvement in the electricity intensity. Three producers of Styrene and Thermal plastic elastomer have multiple products, so their savings data are not considered in Table 7. Because the savings of these three facilities in 2015 are higher than previous year, it is very possible that the actual savings rates of Styrene and Thermal plastic elastomer in 2015 would be higher than in 2014 if the whole savings were able to be contributed to each products.

As to Ethylene, Ethylene glycol and Epichlorohydrin, performance improvements were greater in 2014 than in 2015, although their overall savings rates in 2015 are higher than in 2014.

For Pure Terephthalic acid, Methyl methacrylate, Phthalic anhydride and Polypropylene, overall electrical intensity increased from 2014 to 2015. However, these plants demonstrate positive savings rates in 2015, despite increasing electricity intensity.

The producers of Polycarbonate, Butadiene rubber, Styrene-butadiene rubber, Phenol and Bisphenol A have multiple products. The savings rate of individual product is unable to be calculated because of data restrictions. It is worth noting that the savings of their whole facilities in 2015 are higher than in 2014.

3. Summary

The savings rates and improvement in the electricity intensity of eight petrochemicals, Vinyl chloride, Styrene, Acrylonitrile, Polyethylene, Polyvinyl chloride, Polystyrene, ABS resins and Thermal plastic elastomer, are both better in 2015 than in 2014. The savings rates of Ethylene, Ethylene glycol and Epichlorohydrin in 2015 are also higher than previous year, but these producers show little to no improvement in electrical intensity between 2014 and 2015.

For Pure Terephthalic acid, Methyl methacrylate, Phthalic anhydride and Polypropylene, producers showed positive savings rates but increasing electricity intensity between 2014 and 2015.

As to Polycarbonate, Butadiene rubber, Styrene-butadiene rubber, Phenol and Bisphenol A, the savings of their whole facilities in 2015 are higher than in the previous year, though electrical intensity did not improve.

It appears that the rate of reduction in the electricity intensity of eight petrochemicals increased after the savings target regulation took effect; however, this increase is not observed in other petrochemical processes. In interviews, energy managers at some of these plants explained that technical factors and business issues caused their facilities to consume more energy in 2015, and outweighed or offset the effect of energy conservation measures. In naphtha crackers, heavier feedstock increased the energy intensity of ethylene production. In the processes of Ethylene glycol, high selectiveness catalysts were adopted in recent years, and the reaction generated less waste heat that could be recycled for power generation. The oversupply in Pure Terephthalic acid market is severe, and one producer increased the share of the production of Pure Isophthalic Acid (PIA), whose energy intensity is higher than Pure Terephthalic acid.

Other producers mentioned that they will struggle to maintain reductions in the energy intensity in the future, because customized products offer the potential to generate greater profits. For example, in order to meet higher demand for high viscosity polymer, Polyethylene producers need to use high power extruder to produce it. ABS resins producers continually transfer parts of capacity to the materials applied to toys and components of cars, and the processes of customized products consume more energy than commodity products. Thermal plastic elastomer with weather resistance has wider applications, and its production processes consume more energy than regular products.

4. Conclusion

The target plants in this study show a 19% drop in power consumption between 2010 and 2015. Production declines appear responsible for these reductions in energy consumption in the case of Pure Terephthalic acid, Phthalic anhydride, Polystyrene, Phenol and Bisphenol A. This influence outweighs the increasing power consumption in other petrochemicals because of improvement in electricity intensity in Ethylene, Vinyl chloride, Acrylonitrile, Polyvinyl chloride and ABS resins.

The electricity savings target regulation aims to prompt large energy users to implement more power conservation measures. This study analyses energy data submitted to Bureau of Energy by large energy users in petrochemical industry and targets 57 plants who produce 20 kinds of petrochemicals in their facilities. Overall, the total power savings of target producers increased – more savings were achieved – after the regulation took effect. The savings rates of most petrochemicals in this study are higher in 2015 than in 2014. In the case of Vinyl chloride, Styrene, Acrylonitrile, Polyethylene, Polyvinyl chloride, Polystyrene, ABS resins and Thermal plastic elastomer, the savings rates and electrical intensity both improved after the regulation took effect. In the case of Ethylene, Ethylene glycol and Epichlorohydrin, savings rates increased, but electrical intensity declined little to none between 2014 and 2015. For Pure Terephthalic acid, Methyl methacrylate, Phthalic anhydride and Polypropylene, savings rates increased, even as electrical intensity went up.

Based on thisanalysis, it appears that the mandatory electricity savings target prompted some producers to save more energy, at least in the production of Vinyl chloride, Styrene, Acrylonitrile, Polyethylene, Polyvinyl chloride, Polystyrene, ABS resins and Thermal plastic elastomer.

According to information from interviews with some producers of Ethylene, Ethylene glycol and Pure Terephthalic acid, the negative impacts of some technical factors and business issues on energy consumption offset the effect of energy conservation measures. This information needs quantified data to support itself, however. The authors were unable to verify that these circumstances noted in the interviews are responsible for consumption increases.

References

Petrochemical Industry Association of Taiwan. 2015. *Petrochemical Industry of Taiwan, R.O.C., 2015 Annual Report*.

Bureau of Energy. 2016. *Energy Audit Database, 2016*: Bureau of Energy, Taiwan.