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Analysis of Economic Efficiency on Production of Wood Pellet in Korea

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This study intended to seek measures to enhance competitive power and reduce production cost of Korean wood pellet industry through analysis of wood pellet manufacturing cost. For this, the manufacturing cost, total amount of material cost, labor cost, and other expenses occurred in manufacturing process, was analyzed and sensitivity analysis was conducted to understand change of the manufacturing cost depending on material use pattern change and output increase. As the results, it was analyzed that a factor giving the largest effect to the manufacturing cost of wood pellet was material cost and output. Especially, for the material cost, it was identified as more efficient method to reduce the manufacturing cost to produce wood pellet by mixing lumbering byproducts (sawdust) and forest management products (lumbers) in appropriate ratio rather than to use only lumbering byproducts or forest management products. In addition, because material cost per ton is calculated by dividing labor cost and expenses by output, it was identified as a measure to save the manufacturing cost to maintain output corresponding to production capacity of the manufacturer.

Key words: wood pellet, manufacturing cost, raw material, output, sensitivity analysis

INTRODUCTION

Recently, in order to encounter national energy security and climate change according to high oil prices and Convention on Climate Change, "Low Carbon Green Growth" is promoted as government wide policy and Korea has a plan to expand development and supply of self–supportable new & renewable energy resource strategically. In the National Energy Plan, it is planned to expand new renewable energy supply rate up to 11% and allocate 31% of this energy to bio energy (Ministry for Food, Agriculture, Forestry, and Fisheries, 2008).

In development and supply of new & renewable energy, the wood pellet, a forest biomass, is evaluated as possible to create visible outcome in early stage and having relatively high contribution level in mid and long term. IPCC recommends to substitute bio energy for fossil fuel, assessing that among the alternatives of climate change, the forest had higher flexibility and cost effectiveness (Forest Service, 2010). Wood pellet is recognized as an effective alternative for substituting fossil fuel and reducing greenhouse gas and authorized as a carbon neutral alternative energy with no carbon emission in the Convention on Climate Change (Forest Service, 2009).

Accordingly, Forest Service plans to substitute wood pellet for heating of 140,000 farm houses and 37% of controlled horticulture by 2020 and produce and supply 1 million ton of wood pellet using domestic materials through expansion of forest management product collection by establishing wood pellet energy utilization measures and domestic demand of the wood pellet is expected to increase continuously (Forest Service, 2010).

Additionally, with Renewable Portfolio Standards (RPS) since 2012, it is prospected that future expansion of new renewable energy market will bring increase of demand on wood pellet. Although traditional new renewable energy market focused on solar and wind power, it is prospected that due to introduction of the RPS, new and renewable energy sources with higher RECs (Renewable Energy Certificates) weight, unit price competitive power, facility scalability and electric power generation efficiency will be selected (Korea Environment Institute, 2011). According to Samsung Economic Research Institute, it is expected that when evaluating with 2 axes of RECs weight and power generation efficiency and facility capacity, the market in marine wind power, tidal power, lignocelluloses biomass single firing power generation will be expanded (Samsung Economic Research Institute, 2011).

Like this, while the demand of wood pellet is forecasted to continue to increase due to its supply expansion policy and related systems, it is actually difficult to expand and industrialize the supply of wood pellet without security of economical efficiency in its production.

Besides for wood pellet related socioeconomic previous studies, Korea Forest Policy Research Association (2003) executed studies on economic efficiency, environmentality, and convenience of heating boiler system and the Ministry of Agriculture and Forestry (2005) conducted economic analysis on thermal energy production

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using forest land waste materials, but the subjects were restricted to wood chips. In addition, in the Ministry of Knowledge and Economy (2008) a study on use of lignocelluloses biomass energy using pitch pine (*Pinus rigida*) was performed.

Then with announcement of national vision and policy "Low Carbon and Green Growth" by the president Lee Myung Bak in August, 2008, the importance of wood pellet rose as an effective alternative for fossil fuel substitution and greenhouse gas reduction and some of studies on wood pellet production using forest management product and forest management product collection expenses were executed (Korea Forest Research Institute, 2009). And centering on Korea Forest Research Institute, other several studies were also performed including wood pellet available resource search, wood pellet boiler development, quality comparison of wood pellet, and analysis on production, import, and distribution structure of wood pellet. Moreover, Korea Association of Pellet (2010) analyzed actual and potential state of demand and supply of domestic wood pellet as a research service project of Forest Service and presented brief political direction for wood pellet through short, mid and long term prediction.

However, although in the above previous studies, some studies on raw material collection and production cost of wood pellet were performed, there was no or insufficient economic efficiency analysis study on pellet production using lumbering byproducts and forest management products, main raw materials of wood pellet.

Therefore, this study intends to seek measures to raise competitive power and reduce production cost of future wood pellet industry through analysis on production cost and economic efficiency of pellet production.

MATERIALS AND METHODS

In order to analyze manufacturing cost and economic efficiency of wood pellet production, field work was performed against 10 domestic manufacturers producing wood pellet with public support and private investment (7 public support manufacturers and 3 private investment manufacturers) from June 15, 2012 to July 30, 2012.

However, among them only 5 manufacturers provided data necessary for analysis to accomplish the purpose of this study actively. Especially, the private investment manufacturers were very negative and passive to data supply. Thus, the analysis of manufacturing cost and economic efficiency of wood pellet production was conducted against the above 5 manufacturers.

As analysis tools, the manufacturing cost calculation items including raw material cost (lumbering byproduct and forest management products), wood pellet output per unit, labor cost, depreciation charge, and expenses were used for analysis of total manufacturing cost.

In addition, sensitivity analysis presuming 2 environmental changes such as when the mount of raw material used was changed and when the output increased was

Table 1. Actual state of wood pellet manufacturing facility in Korea

Investment	Year	Area	Business Entity	Facility Scale	Production Capacity (ton)
Government Support	2008	Yeoju	Wood Center	2 ton/hour	7,200
	2009	Cheongwon	Shinyoung E&P	2 ton/hour	7,200
		Gimhae	AJU Recording Development	2 ton/hour	7,200
		Danyang	Forestry Cooperative	2 ton/hour	7,200
		Yangpyeong	Forestry Cooperative	2 ton/hour	7,200
	2010	Muju	Muju–gun	2 ton/hour	7,200
		Pohang	Forestry Cooperative	2 ton/hour	7,200
		Taebaek	Chunglim	1 ton/hour	3,600
		Gwoisan	Poonglim	1 ton/hour	3,600
		Yeongi	Forestry Cooperative	1 ton/hour	3,600
		Sancheong	Forestry Cooperative	1 ton/hour	3,600
		Geochang	Gaemyeong Wood	0.5 ton/hour	1,800
		Pocheon	Gyeonggi Ascon	0.5 ton/hour	1,800
	2011	Gwangyang	Daehyun Wood	2 ton/hour	7,200
		Hwacheon	Hwacheon–gun	0.5 ton/hour	1,800
		Seoguipo	Forestry Cooperative	0.5 ton/hour	1,800
Private Investment	2009	Donghae	Ildo Bio	1 ton/hour	3,600
		Hwasun	SK Forestry	2 ton/hour	7,200
	2010	Pyeongtaek	Green Eco	12,500	7,200
		Jeongsun	Wooju Green	12,500	7,200

conducted to review effect of change of manner to use raw material and change of output on the manufacturing cost of wood pellet

RESULTS AND DISCUSSIONS

Actual state of domestic wood pellet industry

In the commemorative speech of 60th Anniversary National Foundation on August 15, 2008, the President Lee Myung–Bak presented "Low Carbon Green Growth" as national vision of future 60 years. In order to support the low carbon green growth, the government established and is promoting National Energy Plan to expand the supply ratio of new renewable energy to 11% by 2030 and as a part of this, development and supply of wood pellet, a forest biomass became spotlighted in forestry.

According to this, the first commercial producer of wood pellet started to operate in wood centers of National Forestry Cooperative Federation by a government support project in 2008 and then, SK Forest initiated production of wood pellet as the first private investment. Total 16 manufacturers including 4 manufacturers in 2009, 8 manufacturers in 2010, and 3 manufacturers in 2011 came to have wood pellet manufacturing facilities by the government support projects. And investment by private capital got accomplished also and total 3 manufacturers including 1 in 2009 and 2 in 2010 started to produce wood pellet. Thus as of 2012, total 20 firms was established and being operated as the wood pellet manufacturing facility in Korea (Table 1). At present, the production amount of domestic wood pellet is presumes as 104,400 tons a year from the facility scale (ton/hour), but for the construction of wood pellet manufacturing facility, usually about 1 year is required from licensing, to earth–ramming, construction, manufacturing facility, purchase of molding machine, subsidiary construction, and test run of the pellet production line. Therefore, the actual production scale is expected to be much lower than 100,000 tons.

In addition, domestic wood pellet consumption market shows a sharp increase, about 200% every year as 18,216 ton in 2009, 33,751 ton in 2010, and 64,013 in 2011. Among them, domestic wood pellet output supplies about 50% of total consumption and is in increase trend as 8,527 ton in 2009, 13,008 ton in 2010, and 34,335 ton in 2011 (Han Gyu–Seong, 2012). It is expected that the scale of consumption market increase continuously from increase of demand on wood pellet energy application due to future development and supply of new renewable energy.

Manufacturing cost analysis of wood pellet

General status of wood pellet manufacturers

Investment pattern of the 5 subject wood pellet manufacturers was government support. Generally, the cost to install wood pellet manufacturing facility is different according to production scale per hour and 2.5 billion for 2 ton/hr, 1.75 billion won for 1 ton/hr, and 1 billion won for 0.5 ton/hr is required. Government support for these installation cost is provided after public subscription product for support of wood pellet manufacturing facility, which consists of 50% of the national treasury, 20% of local finance, and 30% of self load.

As wood pellet manufacturing facility, 1 manufacturer in 2008, 1 manufacturer in 2009, and 3 manufacturers in 2010 came to be equipped with their manufacturing facilities and their production scale was surveyed as 2 ton/hr (production capacity 7,200 ton/yr) in 3 manufacturers and 1 ton/hr (production capacity 3,600 ton/yr) in 2 manufacturers. As results of survey on monthly average actual output, it was found that A company that started commercial production of wood pellet at the first in Korea in 2008 produced the most as 671 ton, followed by 460 ton of B company, 450 ton of C company, 202 ton of D company, and 100 ton of E company (Table 2). Particularly, the extremely small output of C and D company for their production capacity were associated with test run of their wood pellet manufacturing facility and production line. In order words, because it is usually required for 1 year to construct a wood pellet manufacturing facility from licensing, to earth–ramming, construction, manufacturing facility, purchase of molding machine, subsidiary construction, and test run of the pellet production line, it is known that about 18 months are required for full scale of production. Therefore, even though a company receives government support in this

Table 2. General status of wood pellet manufacturers

Classification	A	B	C	D	E
Investment	Government Support	Government Support	Government Support	Government Support	Government Support
Year of establishment	2008	2009	2010	2010	2010
Facility scale (ton/hr)	2	2	1	1	2
Production capacity (ton)	7,200	7,200	3,600	3,600	7,200
Monthly average production capacity (ton)	681	460	450	202	100
Raw material pattern	Forest management products, lumbering by products	Forest management products	Forest management products	Forest management products	Forest management products

year, time difference occurs until entering into full scale operation of production line (Forest Service, 2011)

In addition, the raw material patterns used for production of wood pellet are classified into 2 types generally. The first case is to use lumbering byproduct produced in timberwork, sawdust, and the second case is to use products or pulp wood produced in forest management (Wood Centers of National Forestry Cooperative Federation, 2010)

When investigating raw material use pattern by the wood pellet manufacturers, it was found that while a company used mixture of forest management products and lumbering byproducts, other 4 manufacturers used forest management products for producing wood pellet. Especially, it was shown that while C company used only pine, a needle leaf tree, other manufacturers used mixture of needle leaf trees and broad leaf trees. It is suggested that this is originated on the characteristics of local forest composition.

Estimation of wood pellet manufacturing cost

Manufacturing cost refers to sum of material cost, labor cost, and expenses generated in manufacturing process (Ministry of Strategy and Finance, 2010). Therefore, wood pellet manufacturing cost means sum of material cost generated in the process of wood pellet manufacturing, which is unit cost required in manufacturing wood pellet with the forest management products (timber) or lumbering byproducts, accompanied labor cost, and expenses (Table 3).

Detailed manufacturing cost of each wood pellet manufacturer is as follows. For material cost, it was found that A company used 70% of lumbering cost (sawdust) and 30% of forest management products and other manufacturers used only forest management products. In order to estimate material cost of A company, it is required to estimate the cost required in manufacturing 1 ton of wood pellet using the lumbering byproducts and the forest management products. At first, the cost estimated by applying actual trade price, 20,000 won/ m^3, to 5.2 m^3 of sawdust required for producing 1 ton of wood pellet with lumbering byproducts and multiplying 70%, the ratio of lumbering byproduct use is 72,800 won/ton. The cost for forest management products, in which 70% of needle leaf trees and 30% of broad leaf tress are used in manufacturing wood pellet, is estimated by applying each ratio of material use to each timber price of needle leaf tree and broad leaf tree and multiplying 1.67 ton, the quantity of pulverized saw dust used in producing 1 ton of wood pellet. In other words, the timber price used in manufacturing 1 ton of wood pellet is estimated as {(price of needle leaf tree 70,000 won/ton × 0.7) + (broad leaf tree 60,000 won/ton × 0.7)} × 1.67 = 111,890 won. When applying 30% to this (111,890 won × 0.3), the ratio of forest management product use, it is calculated as 33,567 won/ton. Therefore, the material cost of A company is 106,367 won/ton, adding the price of lumbering byproducts, 72,800 won/ton, to the price of forest management products, 33,567 won/ton.

The material cost of B, C, D, E company using only the forest management products can be calculated with quantity of raw material input and raw material cost per ton estimated in manufacturing 1 ton of wood pellet. In other words, the material price was estimated by (unit price of timber, raw material cost per ton) × (input ratio)/(yield). As the results, it was analyzed that B company required the smallest material cost among 5 manufacturers as 110,750 won/ton for B company, 8,000 won/ton for C company, 100,000 won/ton for D company, and 102,667 won/ton for E company. This is because the forest management products had higher yield as 75% as well as the lowest price.

The labor cost, which was the wage for labor provided by employees and laborers directly involved in producing wood pellet in the manufacturing field, was estimated by investigating the number of workers and average wage

Table 3. Estimation results of wood pellet manufacturing cost

(Unit: won/ton)

Classification			A	B	C	D	E
Manufacturing Cost	Material cost	Direct material cost	106,367	110,750	80,000	100,000	102,667
	Labor cost	Direct labor cost	28,488	40,000	35,111	41,144	92,260
	Expenses	Depreciation cost	12,126	20,507	9,028	13,226	43,287
		LPG cost	26,825	43,478	21,111	63,624	25,936
		Electric power cost	19,276	28,261	21,778	43,014	40,526
		Repair cost	3,412	6,522	4,889	7,296	10,000
		Package and supplies cost	29,683	30,117	31,000	43,483	42,540
		Other expenses	11,587	10,652	27,267	17,114	16,222
		Total	102,909	139,537	115,073	187,713	178,511
General management expenses (9%)			21,399	26,126	20,717	29,597	33,609
Profit (10%)			15,280	20,566	17,090	25,845	30,438
Total manufacturing cost			274,442	336,979	267,990	384,299	437,485

per person.

Expenses were classified into depreciation cost, LPG cost, electric power cost, repair cost, package and supplies cost and other expenses. For the depreciation cost, straight–line depreciation was applied. In order words it was estimated by applying the number of used years to balance subtracting government support amount from obtained price after grasping all contents of material assets such as pellet machinery, pellet factory, and storage facilities. And the cost required for drying wood pellet, LPG cost and electric power cost, was estimated by applying the amount filled in the survey table by himself. Other expenses include extra–expenses, welfare expenses, insurance, traffic cost, tax and fees, print expenses, and commissions, etc.

In addition, the general cost was estimated by multiplying general management cost rate to the sum of material coast, labor cost and expenses, wherein as the general management cost rate, 9% applied to "manufacturing and purchasing business of wood and wood products" in manufacturing industry prescribed in "planning criteria of estimated cost of financial regulations 200.04–160–7, 2010.4.15" was applied.

The profit refers to operating profit of manufacturer, which was estimated by applying profit rate 10% to sum of labor cost, expenses, and general management cost, excluding material cost from the manufacturing cost.

As shown in the above, as results of estimating manufacturing cost required in producing 1 ton, it was identified that A company had the smallest manufacturing cost as 274,442 won, followed by 267,990 won of C company, 336,979 won of B company, and 437,485 won of E company. The reason that C company had higher total manufacturing cost in spite of much lower raw material cost of at least 20,000 won/ton than A company with the lowest manufacturing cost was because its average output of wood pellet was only 66% of A company. In other words, it is suggested that because in the estimation of manufacturing cost per ton, expenses is calculated by diving labor cost and expenses other than material cost by output, output as well as material cost may give a great effect to the manufacturing cost.

Sensitivity analysis

It is considered that things to give the largest effect to the manufacturing cost of wood pellet is raw material cost, a variable cost inserted into producing 1 ton of wood pellet, rather than invariable costs such as labor cost and expenses and output of wood pellet produced from this.

Thus, sensitivity analysis presuming 2 environmental changes such as when the mount of raw material used was changed and when the output increased was conducted to review effect of change of manner to use raw material and change of output on the manufacturing cost of wood pellet.

Among the 5 manufactures, sensitivity analysis was performed against A company. It was because A company used lumbering byproducts and forest management products as raw materials, so it is possible to understand the effect of manufacturing cost depending on change of raw material use amount. In addition, also for understanding change of manufacturing cost depending on change of output, it was manufacturing wood pellet corresponding to the facility scale (2 ton/hr).

In order to perform full scale of wood pellet production corresponding to the facility scale, considerable period for construction of manufacturing facility and test run of pellet production line is required. D and E company are considered not to approach normal in the aspect of output. Although B and C company can be considered to approach normal stage in the aspect of wood pellet out, but they are excluded because their use of raw materials is restricted in the forest management products.

Change of raw material use pattem

A company, the subject of sensitivity analysis, uses 70% of lumbering byproducts (sawdust) and 30% of forest management products (timber) as raw materials. Thus, in order to review the effect of change of raw material use pattern on the manufacturing cost of wood pellet, 4 scenarios were presumed. Thus, in order to review the effect of change of raw material use pattern on the manufacturing cost of wood pellet, 4 scenarios were presumed.

In addition, it was presumed that although the material cost per ton and general management cost were changed in manufacturing wood pellet, invariable costs such as labor cost and expenses were not change. Scenario 1 was the case that use ratio of the lumbering byproducts (saw dust) was 100%, scenario 2 was the case that use ratio of the forest management products (timber) was 100%, Scenario 3 was the case that the use ratio of the lumbering byproducts (saw dust) versus the forest management products (timber) was 80%:20%, and scenario 4 was the case that the use ratio of the lumbering byproducts (saw dust) versus the forest management products (timber) was 90%:10%.

As results of sensitivity analysis depending on change of raw material use pattern, it was identified that the

Table 4. Example of material cost estimation of B company using only forest management products

Classification	Average price per ton	Input ratio	Yield	Unit price
Needle–leaf trees	67,500 won	70%	60%	78,750 won
Broad– leaf trees	64,000	30%		32,000 won
Raw material cost per ton				110,750 won

Note: Unit price = (average price × input ratio) / yield

scenario 3 where the use ratio of the lumbering byproducts (saw dust) versus the forest management products (timber) was 80%:20% had the lowest manufacturing cost per ton as 266,359 won/ton, followed by the scenario 4 where the use ratio of the lumbering byproducts (saw dust) versus the forest management products (timber) was 90% : 10% as 269,100 won/ton (Table 5). Comparing 274,442 won, the result of wood pellet manufacturing cost estimation shown in Table 3, it was analyzed that the scenario 3 was 2.9% lower and the scenario 4 was 1.9% lower than that. On the contrary, it was identified that the scenario 2 that used only the forest management products (timber) showed the highest manufacturing cost and the scenario 1 using only lumbering byproduct (saw-dust) showed the second higher manufacturing cost.

Therefore, it seems that the measure to save manufacturing cost is to mix the lumbering byproducts and the forest management products in appropriate ratio rather than using only one of them as raw materials.

Output Change

A company, the subject of sensitivity analysis, has 2 ton/hr of facility scale and 7200 ton/yr of annual production capacity. Its operation time per day is 24 hours, and it produces monthly average 681 tons of wood pellet. Its operation time per day is 24 hours, and it produces monthly average 681 tons of wood pellet. As explained in the above, as the material cost per ton is calculated by dividing labor cost and expenses by output, output may give a great effect to the manufacturing cost. Therefore, when the output increases further, the manufacturing cost is reduced further. However although the output cannot be increased unlimitedly in terms of wood pellet manufacturing facility size, how much effect it gives to the manufacturing cost in producing 8000, 9,000, 10,000 tons of wood pellet within the range not exceeding 30% of annual production capacity was reviewed. Provided, it was presumed that the material cost was not changed.

As results of sensitivity analysis depending on output change, it was analyzed that in case of producing 9,000 ton and 10,000 ton a year, the manufacturing cost per ton were 4.8% lower and 9.5% lower than 274,442 won, the result of wood pellet manufacturing cost per ton estimation shown in Table 3, as 261,285 won and 248,347 won respectively (Table 6).

CONCLUSION

This study intended to seek measures to raise competitive power and reduce production cost of future wood pellet industry through analysis on material cost of pellet production.

For analysis of wood pellet manufacturing cost, the manufacturing cost calculation items including raw material cost (lumbering byproduct and forest management

Table 5. Sensitivity analysis results depending on raw material use pattern

(Unit: won/ton)

Classification	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Material cost	104,000	139,667	99,012	101,506
Labor cost	28,488	28,488	28,488	28,488
Expenses	102,909	102,909	102,909	102,909
General management expenses (9%)	21,186	24,396	20,737	20,961
Profit (10%)	15,258	15,579	15,213	15,236
Total manufacturing cost	271,841	311,038	266,359	269,100

Note: 1. Scenario 1 is the case that the use ratio of lumbering byproduct (saw dust) is 100%
2. Scenario 2 is the case that the use ratio of forest management product (timber) is 100%
3. Scenario 3 is the case that the use ratio of the lumbering byproducts (saw dust) versus the forest management products (timber) is 80%:20%
4. Scenario 4 is the case that the use ratio of the lumbering byproducts (saw dust) versus the forest management products (timber) is 90%:10%

Table 6. Results of sensitivity analysis depending on output change

(Unit: won/ton)

Classification	8,000 ton	9,000 ton	10,000 ton
Material cost	106,367	106,367	106,367
Labor cost	29,085	25,867	23,289
Expenses	104,815	94,557	86,344
General management expenses (9%)	21,624	20,411	19,440
Profit (10%)	15,552	14,083	12,907
Total manufacturing cost	277,443	261,285	248,347

products), wood pellet output per unit, labor cost, depreciation charge, and expenses were used for analysis of total manufacturing cost against 5 wood pellet manufactures. In addition, sensitivity analysis presuming 2 environmental changes such as ① when the mount of raw material used was changed and ② when the output increased was conducted to review how much effect the change of raw material use pattern and output gives to the manufacturing cost of wood pellet.

As the results, it was analyzed that the factors giving the largest effect to the manufacturing cost of wood pellet were material cost and output. Especially, it was identified that as the raw material cost might have about 20,000 won of difference depending on characteristics of regions where the manufacturer was located, it gave great effect to the material cost of wood pellet. Additionally, it is suggested that as the material cost per ton is calculated by dividing labor cost and expenses by output, output may give a great effect to the manufacturing cost. In other words, it is considered that when output increases further, the manufacturing cost can be reduced further.

Besides, as results of case study on the effect of raw material pattern and output change on the manufacturing cost of wood pellet, it was identified that it was a measure able to save 2~3% of manufacturing cost to use the mixture of the lumbering byproducts and the forest management products in appropriate ratio rather than each of the lumbering byproducts and the forest management products. In addition, it was analyzed that when producing wood pellet exceeding the annual production capacity (7,200 ton) by about 30% (10,000 ton), it was possible to save the manufacturing cost by 9.5%.

Therefore, it is considered that in order to raise competitive power through reduction of wood pellet manufacturing cost in future, the measure to increase output as well as appropriate input of lumbering byproduct shall be preceded rather than single pattern use of raw material.

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