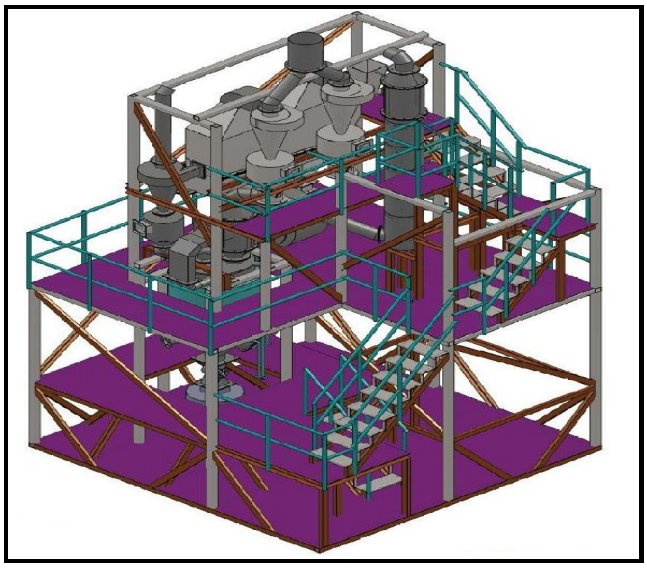
Flash pyrolysis plant to convert the saw dust, sugarcane bagasse, biomass residues, lignite & coal into syn-oil, syn-gas & carbon



Introduction –

GoodRich offers flash pyrolysis plants from Russia in 3 models, i.e., FP-10, FP-20 & FP-40. The input capacity of FP-10 model is 10,000 tons per year; FP-20 model is 20,000 tons per year and FP-40 model is 40,000 tons per year.

Pyrolysis is the thermal decomposition of input materials with limited oxygen access, which takes place at relatively low temperatures (500-900^{0}C) as compared to gasification (800-1,300^{0}C) and burning (900-2,000^{0}C) processes. Compared to gasification or burning, pyrolysis is highly efficient, but it is the least developed technology as on date.

Flash pyrolysis plant can use the saw dust, wood wastes, plywood and furniture factory wastes, all kinds of biomass and agricultural wastes including paddy husk and sugarcane bagasse, corn stalk, cotton stalk, lignite, coal or poultry litter of broilers as the feed stock. Russian flash pyrolysis technology is a result of 40 years of research made by the scientists of the former Soviet Union. An experimental plant was set up in 2008, the FP-10 model was set up in 2013; FP-20 model in 2014 and FP-40 model in 2017.

In the process, raw materials are crushed to 0-3 mm size & dried to less than 2% moisture, using a fluid bed drier. Pyrolysis is an exothermic process & the heat generated in the reaction is used for drying. The dried materials are flash-pyrolysed in less than 6 seconds on a hot metal bed, in the temperature range of 500-900^{0}C.The resulting products are passed through a gas cleaning unit to separate syn-oil (a furnace oil /diesel substitute), syn-gas (a natural gas substitute) & high-carbon material. The syn-oil burns like diesel & the syn-gas burns like natural gas. High-carbon material contains up to 90% carbon.

The output energy from the flash pyrolysis plant is 1.5-2 times higher than its input energy. This is due to the fact that during pyrolysis, oxygen is removed from the feed stock, which otherwise combines with hydrogen to form water.

By removing oxygen from the feedstock in the drying & pyrolysis processes, energy in the hydrogen is completely utilized by way of hydrocarbons. Flash pyrolysis combines molecular & quantum physics along with thermodynamics. Russians call this technology as revolutionary, as it can simply double the energy resources of the world.

In the pyrolysis reactor, micro-bursting takes place. The inter-molecular & intra-molecular bonds between the chemical elements are broken, synthesizing new bonds that surpass the original ones in terms of energy value. The traditional energy conservation law is not applicable for specific heats of substance-burning here, as the effect of 'fast heat stroke on the substance particle' is employed. In flash pyrolysis, a number of Russian design & engineering institutes have been involved.

The syn-gas and syn-oil can be produced at 20-25% of the current prices of natural gas and furnace oil for equivalent energy value, resulting in enormous savings.

What is pyrolysis?

Pyrolysis is the decay or decomposition of organic & inorganic compounds during thermal exposure. The process of pyrolysis is already used to convert hydrocarbons into ethylene & propylene. Currently, world's production of 113 million tons of ethylene & 40 million tons of propylene are through pyrolysis. Other important products of pyrolysis are butadiene & benzene. Currently, through fast pyrolysis of hydrocarbons, 80% of world's butadiene & 39% of world's benzene are produced.

During the flash pyrolysis of biomass, complex compounds are converted into hydrocarbons with smaller molecular weights. Thermal efficiency of the flash pyrolysis process is 91-93% & the overall performance is 7-8 times better than other comparative technologies.

Comparison between the existing technologies in the world, for flash pyrolysis –

Name	BTG (Netherlands)	RTP (Italy)	FP-40 (Russia)
Type of Reactor	Ablative (cone in a cone)	CFB (circulating fluidized bed)	Ablative (plate)
Raw material size	< 2 mm	< 2 mm	< 3 mm
Thermal agent	Sand, nitrogen	Sand, recycled gases	Metal
Requirement of external energy	Permanent	Permanent	Only when started
Major overhauling period	18,000 hours	18,000 hours	80,000 hours
Purity of the products	Average	Average	High
Specific capital investments per ton of annual feed stock	350 USD	400 USD	40 USD
Payback period	48 months	60 months	12 months

Products of flash pyrolysis plant –

- Syn-gas – 300 to 700 cubic metres per ton of dry weight of the raw material. Its calorific value ranges from 6,000- 8,000 Kcal/m^3. It can be used for all the purposes where natural gas is being used. It burns clean & reaches high temperatures.

- Syn-oil – 100 to 600 kgs per ton of dry weight of the raw material. Its calorific value ranges from 7,000-9,000 kcal /kg. It can be used as a burning medium in place of diesel / furnace oil in boilers, kilns, furnaces & oil generators. By increasing the height of the rectifier column or by increasing its pressure, light & heavy oils can be recovered separately in the process.

- High-carbon material – 150 to 300 kgs per ton of dry weight of the raw material, with calorific values ranging from 3,000-7,000 kcal/kg & carbon contents up to 90%. It can be used as a source of high purity carbon in ferro alloys, steel & other metallurgical plants, in tyre making, food industries, medicine (to replace activated carbon) and as a source of heat in furnaces & kilns (to replace the pet coke). Its particle size is less than 1.5 mm and after briquetting, it can also be used for all the applications of charcoal.

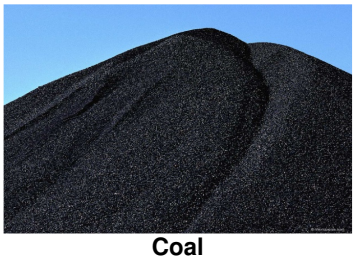
Input & output values of flash pyrolysis –

Following are the maximum recoveries of gas, oil & carbon from the flash pyrolysis process, as compared to the carbonisation (charcoal making) process –

Features	Low temperature setting in flash pyrolysis for maximum recovery of oil	High temperature setting in flash pyrolysis for maximum recovery of gas	Carbonisation (slow pyrolysis or charcoal making process)
Processing time	Up to 6 seconds	Up to 6 seconds	24 to 36 hours
Raw material size	Up to 3 mm	Up to 3 mm	Large
Input material moisture	Up to 8%	Up to 8%	High
Temperature	500-700^{0}C	700-900^{0}C	400-600^{0}C
Pressure	100 kPa	100 kPa	100 kPa
Output of syn-gas (% mass of dry material)	Up to 30%	Up to 70%	Up to 40%
Heat value of syn-gas (kcal/m^3)	6,000 - 8,000	6,000 - 8,000	500 - 1,000
Output of syn-oil (% mass of dry material)	Up to 60%	Up to 10%	Up to 20%
Heat value of syn-oil (kcal/kg)	7,000 – 9,000	7,000 – 9,000	2,400-4,800
Output of carbon (% mass of dry material)	Up to 30%	Up to 30%	30-40%
Heat value of carbon (kcal/kg)	Up to 7,000	Up to 7,000	Up to 8,000

Note: The flash pyrolysis plant can take any moisture up to 30%. However, in such a case, the quantity of dried raw material will come down and the overall plant capacity will decrease. Hence it is desirable to install an external drier, to dry the raw material up to 8-12% moisture.

Raw materials for flash pyrolysis plant–

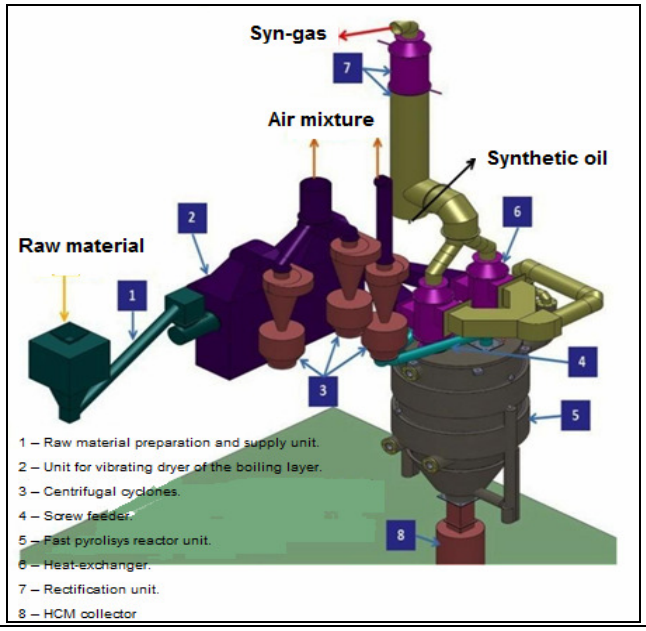
 Lignite	 Coal	 Peat
 Straw	 Poultry litter	 Saw dust
 Sugarcane bagasse	 Paddy husk	 Paper waste
 Plantation wood	 Hulls & peelings	 Biomass

Applications of flash pyrolysis -

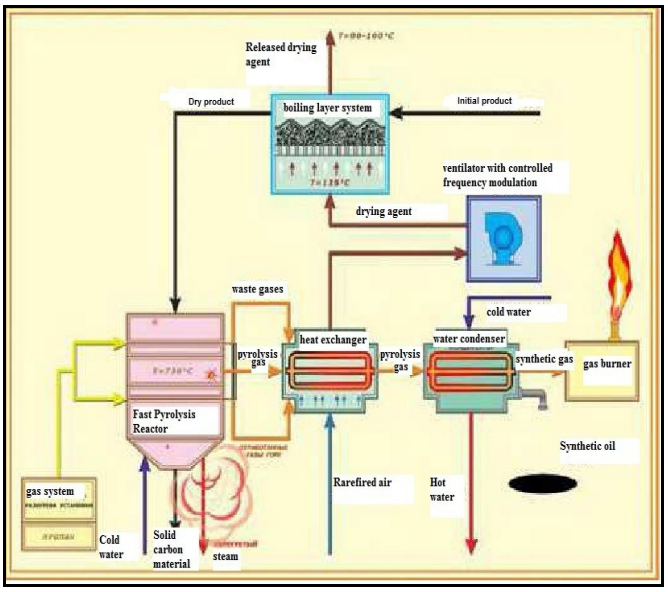
- To replace the natural gas & furnace oil in boilers, glass melting units, re-heating furnaces of steel rolling mills, iron ore pelletisation plants, alumina sintering plants, aluminium & copper melting units, refractory & ceramic kilns, DRI making tunnel kilns etc., where such applications need high-temperature gases. For these thermal applications, the investment will pay-back within a year.

- To generate electricity at 50% of the present cost by sugar factories, rice mills & independent power plants. Syn-oil & high-carbon material can recover half of the raw material cost. The electricity can be generated either by the traditional boiler-turbine route or by employing low RPM gas generators of 0.3 MW to 1 MW ratings.

3 D view of the flash pyrolysis plant



Simplified scheme of the flash pyrolysis plant-



Following are the recovery figures of oil, gas & carbon from some of the raw materials -

1. Output of products from the processing of 1 ton of wood waste –

Processed products	Output, depending on the reactor temperatures		
	520 ^{0}C	700 ^{0}C	830 ^{0}C
Liquid fraction, kgs	300	450	220
Syn-gas, kgs	115	200	415
High carbon material, kgs	300	115	80

2. Output of products from the processing of 1 ton of paddy husk -

Processed products	Output, depending on the reactor temperatures		
	520 ^{0}C	700 ^{0}C	860 ^{0}C
Liquid fraction, kgs	27	45	20
Syn-gas, kgs	145	270	560
High carbon material, kgs	700	270	190

3. Output of products from the processing of 1 ton of lignite -

Processed products	Output, depending on the reactor temperatures		
	620 ^{0}C	780 ^{0}C	930 ^{0}C
Liquid fraction, kgs	140	240	160
Syn-gas, kgs	80	100	220
High carbon material, kgs	280	160	120

4. Output of products from the processing of 1 ton of coal-

Processed products	Output, depending on the reactor temperatures		
	690 ^{0}C	800 ^{0}C	950 ^{0}C
Liquid fraction, kgs	340	440	240
Syn-gas, kgs	100	200	480
High carbon material, kgs	530	330	250

5. Output of products from the processing of 1 ton of coal sludge -

Processed products	Output, depending on the reactor temperatures		
	650 ^{0}C	800 ^{0}C	950 ^{0}C
Liquid fraction, kgs	100	140	90
Syn-gas, kgs	40	50	140
High carbon material, kgs	180	130	90

6. Output of products from the processing of 1 ton of peat-

Processed products	Output, depending on the reactor temperatures		
	500 ^{0}C	680 ^{0}C	870 ^{0}C
Liquid fraction, kgs	170	300	120
Syn-gas, kgs	30	60	280
High carbon material, kgs	300	140	100

7. Output of products from the processing of 1 ton of raw shale –

Processed products	Output, depending on the reactor temperatures		
	570 ^{0}C	750 ^{0}C	870 ^{0}C
Liquid fraction, kgs	100	200	70
Syn-gas, kgs	70	70	220
High carbon material, kgs	250	150	130

Basis for selection of raw materials –

Output in the pyrolysis plant increases –

- By decreasing the initial moisture level of the raw material (increases the gas volume); &
- By increasing the volume of biomass in the mixture (increases the gas calorific value).

Compliance to these two principles at the stage of selection & preparation of the raw material allows achieving maximum productivity in terms of gas volume & gas calorific value.

Photo of Syn-gas from the flash pyrolysis-

Following are the energy balances of some of these raw materials–

Composition	Saw dust / sugarcane bagasse / other biomass (%)	Paddy husk (%)	Indone-sian thermal coal (%)
Moisture (dried to 10%)	10	10	10
Carbon	42.9	34.9	58.6
Hydrogen	5.3	4.6	4.1
Oxygen	36.5	34.1	11.8
Nitrogen	0.6	2.0	1.0
Sulphur	0.2	0.1	0.6
Ash	4.5	14.3	13.9
Total	**100%**	**100%**	**100%**
Gross calorific value (as per DULONG formula)	3,724 Kcal/kg	2,938 Kcal/kg	5,654 kcal/kg
Net calorific value (as per DULONG formula)	3,444 Kcal/kg	2,695 Kcal/kg	5,437 kcal/kg
Recoveries from the flash pyrolysis plant–			
- Recovery of oil (kgs / ton)	450	20	440
- Minimum heat value of oil (kcal/kg)	7,000	7,000	7,000
- Recovery of syn-gas (kgs/ ton)	200	560	200
- Minimum heat value of syn- gas (kcal/kg)	6,000	6,000	6,000
- Recovery of high carbon material (kgs/ ton)	115	190	330
- Minimum heat value of high carbon material (Kcal/kg)	6,000	2,000	4,000
- Net calorific value of all the above 3 products	5,040 kcal/kg	3,880 kcal/kg	5,600 kcal/kg
- Net output - energy recovered, as a percentage of net input - energy	146%	144%	103%

Syn-oil parameters (using peat) from the flash pyrolysis-

Compound	Representatives	Concentration, % mass
Alkans - saturated hydrocarbons	Pentane (C5H12) etc. до C16H34 + cyclopenthane, cyclohexane, 1,2-ethylcyclohexane	56.6
Alkadienes – unsaturated hydrocarbons	2-methyl-butadien 1,3(isoprene) etc.	10.8
Aromatic hydrocarbons	Benzene (C6H6) от 1,2-dimethylbenzene (ortho-xylol) up to 1,4-dimethylbenzene, toluene, vanilin etc.	14.3
Hydroxils	Alcohols (methanol, diols, triols etc). Phenols (hydroxybenzene, 3-methylphenol etc) Esters (benzole acid etc.)	14.6
Carbonils	Aldehydes (3,4,5-trimethoxibenzaldehid, dimetoxisalycillic aldehyde, 5-methyl-2-furancarboxaldehyde) Ketones(dymethilketone) acetone etc.)	2.2
Carbonic acids	Aromatic acids; Penthane acid etc	0.3
Esters	Ethyl acetate, methyl benzoate etc.	0.1
Nitrogen-containing	Nitromethane, nitrobenzene;Amines; Carbamide; Amino acids	1.1
	Total	**100.0**

Note**:** Oil density is 0.8-1.0 gram/cm^3

Parameters of high carbon material from the flash pyrolysis –

Characteristic	Value
Volume of particles	0.5-1.5 mm
Carbon percentage	Up to 95.5%
Hydrogen percentage	Up to 0.8%
Oxygen percentage	Up to 0.7%
Nitrogen percentage	Up to 1.1%
Calorific value per kg	6,900-7,400 Kcal

Syn-gas composition from the flash pyrolysis –

Component	Fraction, % mass.
H_2	10.0 – 35.0
O_2	4.0 – 10.0
N_2	3.0 – 6.0
CH_4, C_2, C_3, C_4	30.0 – 55.0
CO_2	Traces
CO	15.0 - 25.0
Heat value	6,000 – 8,000 kcal/ m^3
Density Kg/m^3	From 0.8

Notes:

1. The final gas temperature is around 30^0C.
2. The gas composition can be changed by changing the process temperatures. The H_2 & CO contents can be reduced up to 1.5% each & O_2 content, to less than 5%.
3. The gas comes out without any pressure (less than 1 atm). It can be fed to a compressor that pressurizes the gas & fills into a gas tank, with the desired pressure.

The syn-gas from the flash pyrolysis plant contains large amounts of hydrogen & hydrocarbons. While burning, it sharply reduces the harmful exhausts (CO, CO_2) and is hence environmentally clean. No other harmful products are generated from the organic raw materials.

Utilities needed for FP-40 Plant –

- Required plant area - 100 m^3
- Height of construction - 10 metres
- Propane / LPG (to automatically control the reactor temperature) - up to 2,000 litres/year
- Electricity - 60 kWh
- Water - Up to 20 m^3 per day
- Supervisory staff for plant operation - 2 persons per shift

Note: Annual consumption of propane gas is only 600 kgs in case of continuous operation.

Scope of supply & prices –

FP-10 / FP-20 / FP-40 plants can be supplied on turn-key basis, including the feeding system of raw material to the plant. The cost includes –

- Designing
- Manufacturing
- Supply
- Installation at site & start-up
- Training the staff
- Initial supervision &
- 2 years of warrantee services.

The supply period is 6 months. The plant can be run continuously for 330 days in a year. It needs preventive maintenance for 7 days in a year. The equipment life is 20 years. It needs major overhauling only after 10 years.

The investments on the flash pyrolysis plants are –

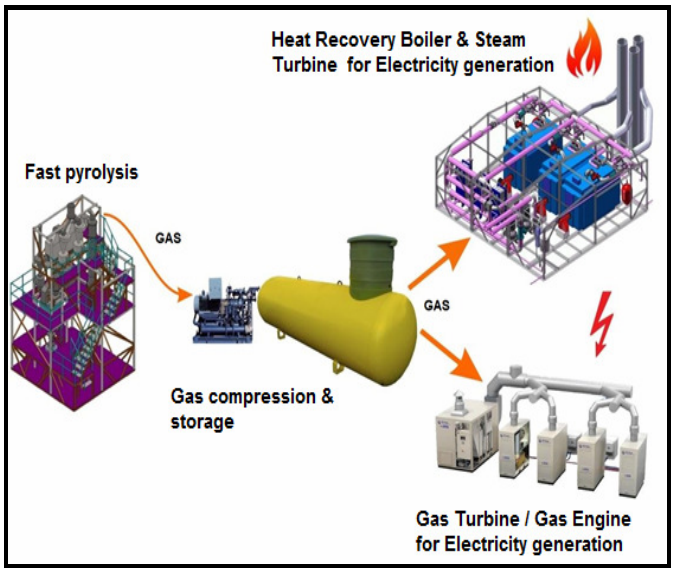
- FP-10 model - Rs. 5 crores
- FP-20 model - Rs. 7.5 crores
- FP-40 model - Rs. 10 crores

Notes:

1) The cost of gas generators for the power plant will be extra at Rs. 3 crores per MWh.

2) The local equipments include gas holder, gas compressor, pipes and the machines needed for the preparation of raw materials (crusher for wood wastes, dryer for saw dust and bagasse to reduce the moisture up to 12% and hopper for the raw material storage).

The scheme of mini thermo-electric plant on the basis of gas generation in FP-10, FP-20 & FP-40 units-



Cost of production, profitability and investment estimates for flash pyrolysis plants of 40,000 tons/year –

A. Cost of production & profitability estimates –

	Wood waste	Sugar-cane bagasse & other biomass	Paddy husk	Indo-nesian ther-mal coal
Price of raw material per ton	Rs. 3,000	Rs. 2,000	Rs. 3,000	Rs. 5,000
Initial moisture content	30%	40%	10%	20%
Effective cost per ton, on bone-dry basis	Rs. 4,300	Rs. 3,300	Rs. 3,300	Rs. 6,300
Add: Cost of processing per ton, including drying, pyrolysis, carbon briquetting, packing, manpower & maintenance	Rs. 600	Rs. 700	Rs. 400	Rs. 500
Total cost of input per ton	**Rs. 4,900**	**Rs. 4,000**	**Rs. 3,700**	**Rs. 6,800**
Recovery of oil (kgs per ton)	450	450	20	440
Recovery of syn-gas (kgs per ton)	200	200	560	200
Recovery of carbon material (kgs per ton)	115	115	190	330
Revenue from oil @ Rs. 20,000 per ton (heat value – 7,000 kca/kg)	Rs. 9,000	Rs. 9,000	Rs. 400	Rs. 8,800
Revenue from syn-gas (6,000 kcal/kg, which can generate 2 KWh of electricity by using gas generators, @ Rs. 5 per KWh of electricity)	Rs. 2,000	Rs. 2,000	Rs. 5,600	Rs. 2,000
Revenue from carbon material @ Rs. 8,000 per ton	Rs. 920	Rs. 920	Rs. 380 (Rs. 2,000 per ton only, due to high ash)	Rs. 990 (Rs. 3,000 per ton only, due to high ash)
Total value of output per ton	**Rs. 11,920**	**Rs. 11,920**	**Rs. 6,380**	**Rs. 11,790**
Net margins per ton	Rs. 7,020	Rs. 7,920	Rs. 2,680	Rs. 4,990
Profit before taxation	Rs. 19.66 crores	Rs. 19.00 crores	Rs. 9.65 crores	Rs. 15.97 crores
Total investment	Rs. 16.00 crores (with 2 MWh power plant)	Rs. 16.00 crores (with 2 MWh power plant)	Rs. 25.00 crores (with 5 MWh power plant)	Rs. 16.00 crores (with 2 MWh power plant)
Pay-back period at 100% capacity utilization	**1 year**	**1 year**	**3 years**	**1 year**

B. Investments –

(Rs. in crores)

	FP-10 (input capacity - 10,000 tons/year)		FP-20 (input capacity – 20,000 tons /year)		FP-40 (input capacity – 40,000 tons /year)	
	With maximum oil recovery option	With maximum gas recovery option	With maximum oil recovery option	With maxi-mum gas recovery option	With maximum oil recovery option	With maximum gas recovery option
Flash pyrolysis main plant	3.00	3.00	4.50	4.50	6.00	6.00
Add: taxes & duties, transport, erection, commissioning & trial run	0.75	0.75	1.10	1.10	1.30	1.30
Oil filling, gas holder, compressor, etc., & buildings	0.75	0.75	1.10	1.10	1.30	1.30
Raw material preparation such as crushing, screening & drying	0.50	0.50	0.80	0.80	1.40 (needs an external drier)	1.40 (needs an external drier)
Total investment without power plant	**5.00**	**5.00**	**7.50**	**7.50**	**10.00**	**10.00**
Gas generators for power plant, including electricals	1.50 (0.5 MWh)	3.00 (1 MWh)	3.00 (1 MWh)	6.00 (2 MWh)	6.00 (2 MWh)	12.00 (4 MWh)
Total investment with the power plant	**6.50**	**8.00**	**10.50**	**13.50**	**16.00**	**22.00**

Photos of FP-20 flash pyrolysis plant

The investments on the flash pyrolysis plants range from Rs. 5 to 10 crores, depending on their production capacities. The pay-back period is around 1 year, when used as a replacement for natural gas / diesel, or 3 years when used for power generation.