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Pyrolysis:
A waste management approach for
the
Peace River
Regional District
An economic and environmental evaluation
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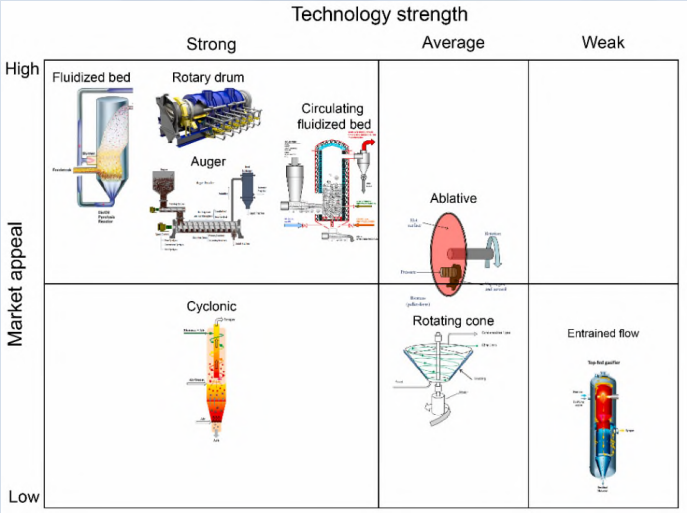
Pyrolysis background

1.



Some common pyrolysis technologies

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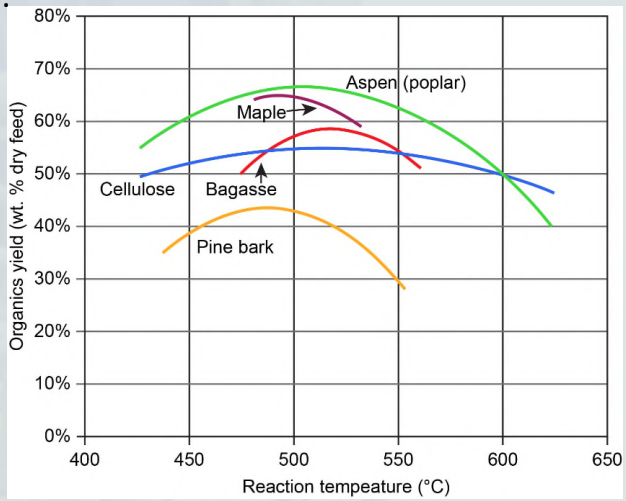
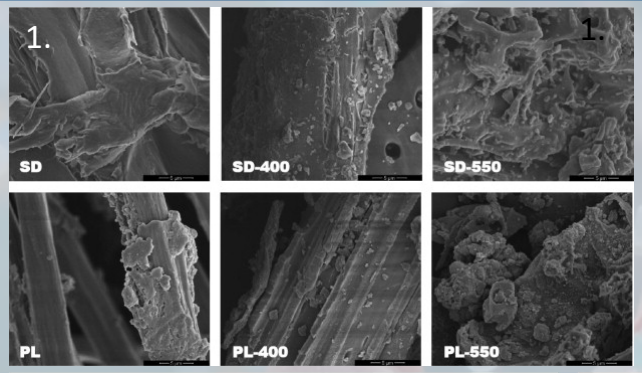


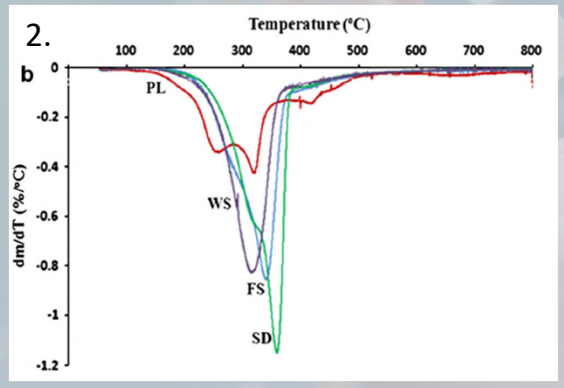
Distribution of products varies with temperature.

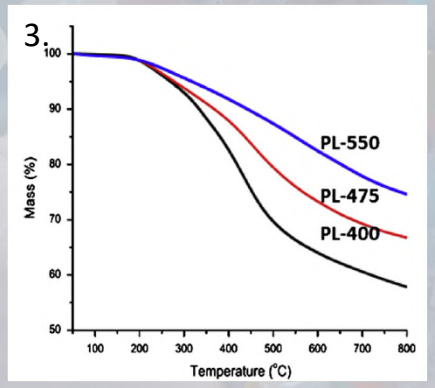
1. Campuzano, F.; Brown, R. C.; Martínez, J. D. Auger Reactors for Pyrolysis of Biomass and Wastes. *Renew. Sustain. Energy Rev.* **2019**, *102*, 372–409. https://doi.org/10.1016/j.rser.2018.12.014.
2. Jouhara, H.; Czajczyńska, D.; Ghazal, H.; Krzyżyńska, R.; Anguilano, L.; Reynolds, A. J.; Spencer, N. Municipal Waste Management Systems for Domestic Use. *Energy* **2017**, *139*, 485–506. https://doi.org/10.1016/j.energy.2017.07.162.
3. Bridgwater, A. V. Review of Fast Pyrolysis of Biomass and Product Upgrading. *Biomass and Bioenergy* **2012**, *38*, 68–94. https://doi.org/10.1016/j.biombioe.2011.01.048.

Pyrolysis background



1. SEM of biochars from sawdust (SD) and poultry litter (PL) at various temperatures.
2. Loss of mass for various feedstocks with change in temperature. Major mass loss up to 500°C.
3. Mass losses by temp for poultry litter.





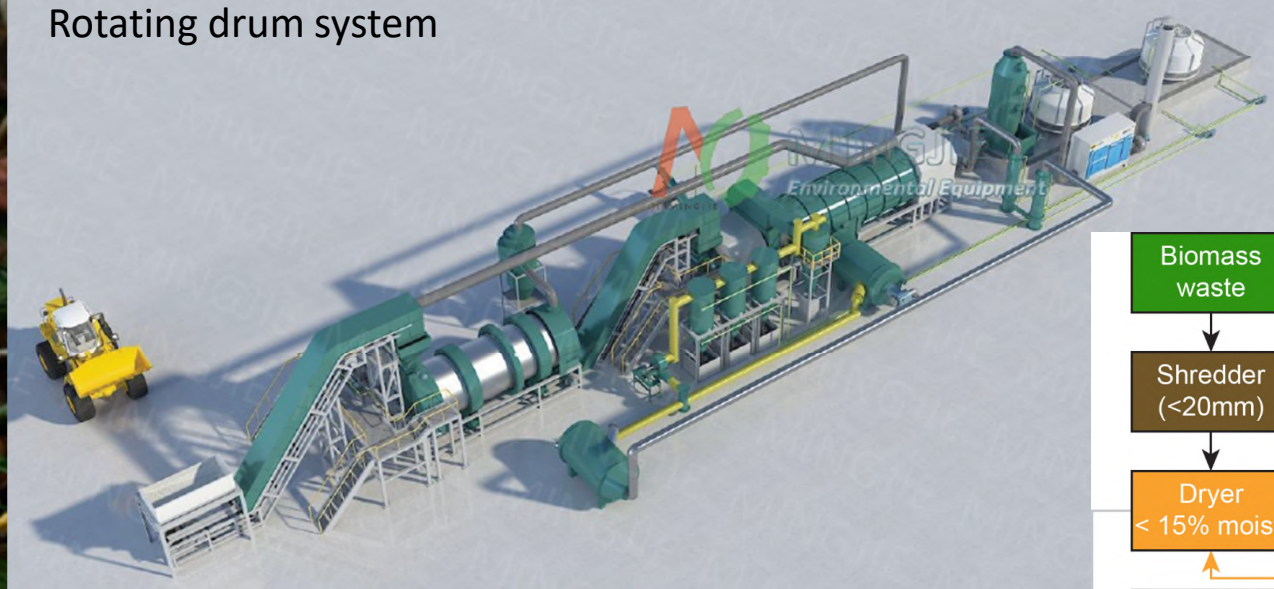
Consider the application

- PL has higher ash content = more nutrients (soil amender).
- Higher temp reduces ash, but more carbon fusion, less active (need to be activated; water purification).

1. Azargohar, R.; Nanda, S.; Kozinski, J. A.; Dalai, A. K.; Sutarto, R. Effects of Temperature on the Physicochemical Characteristics of Fast Pyrolysis Bio-Chars Derived from Canadian Waste Biomass. *Fuel* **2014**, *125*, 90–100. https://doi.org/10.1016/j.fuel.2014.01.083.

Sub-regional "pilot scale" pyrolysis plant: MJT-500

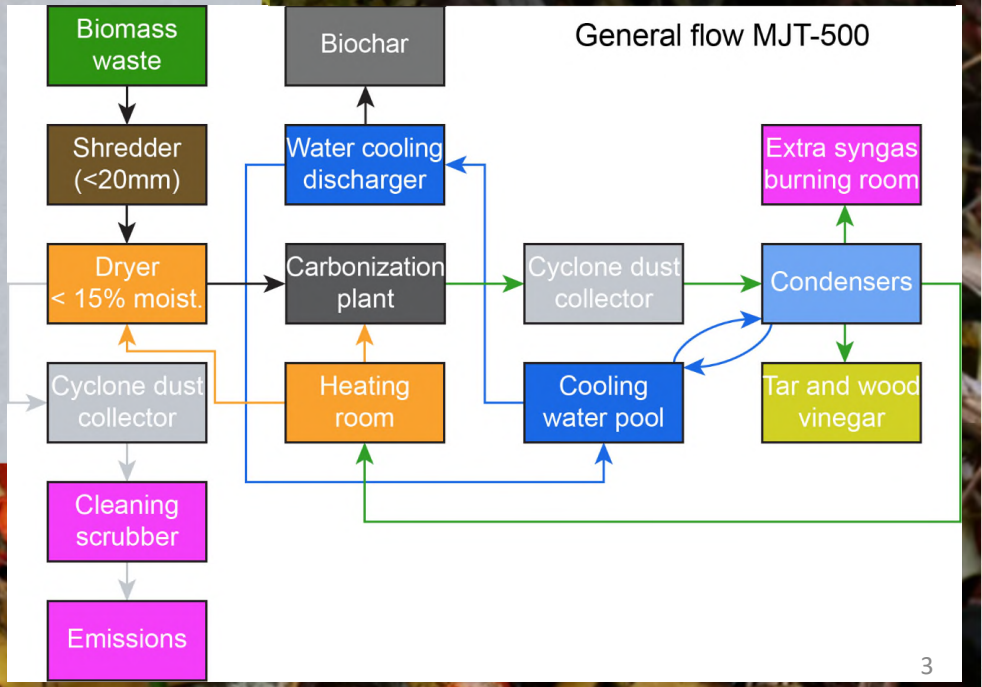
~$300,000
Rotating drum system



- 500 kg/h operating
  - 90% uptime, 5 days/week, 40 hours per day: 936 annual tonnes (dry) or ~3,153 t wet @ 70% assumed moisture for FW

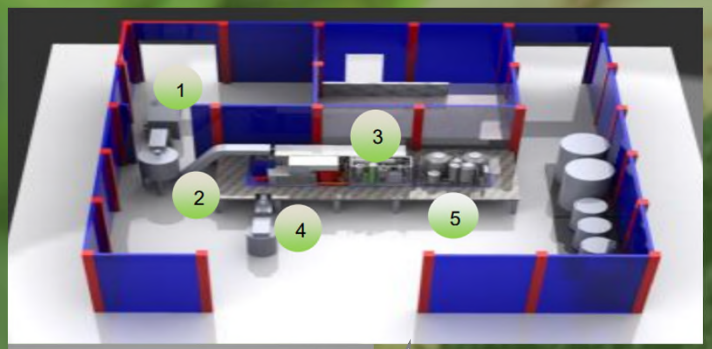
*80% for grass (GW), 60% for wood

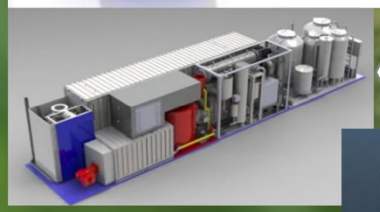
Days	Hours (h)	Per week	Annual (h)	Tonnage wet
5	8	40	1,872	3,200
5	16	80	3,744	6,400
7	24	168	7,863	12,000 (used)



Regional pyrolysis solution: ATS-1000

~$9.8 million





Reactor

Oil & gas treatment

Oil & water treatment

- 1,500 kg/h operating
  - FW, GW, plastics, textiles, tires

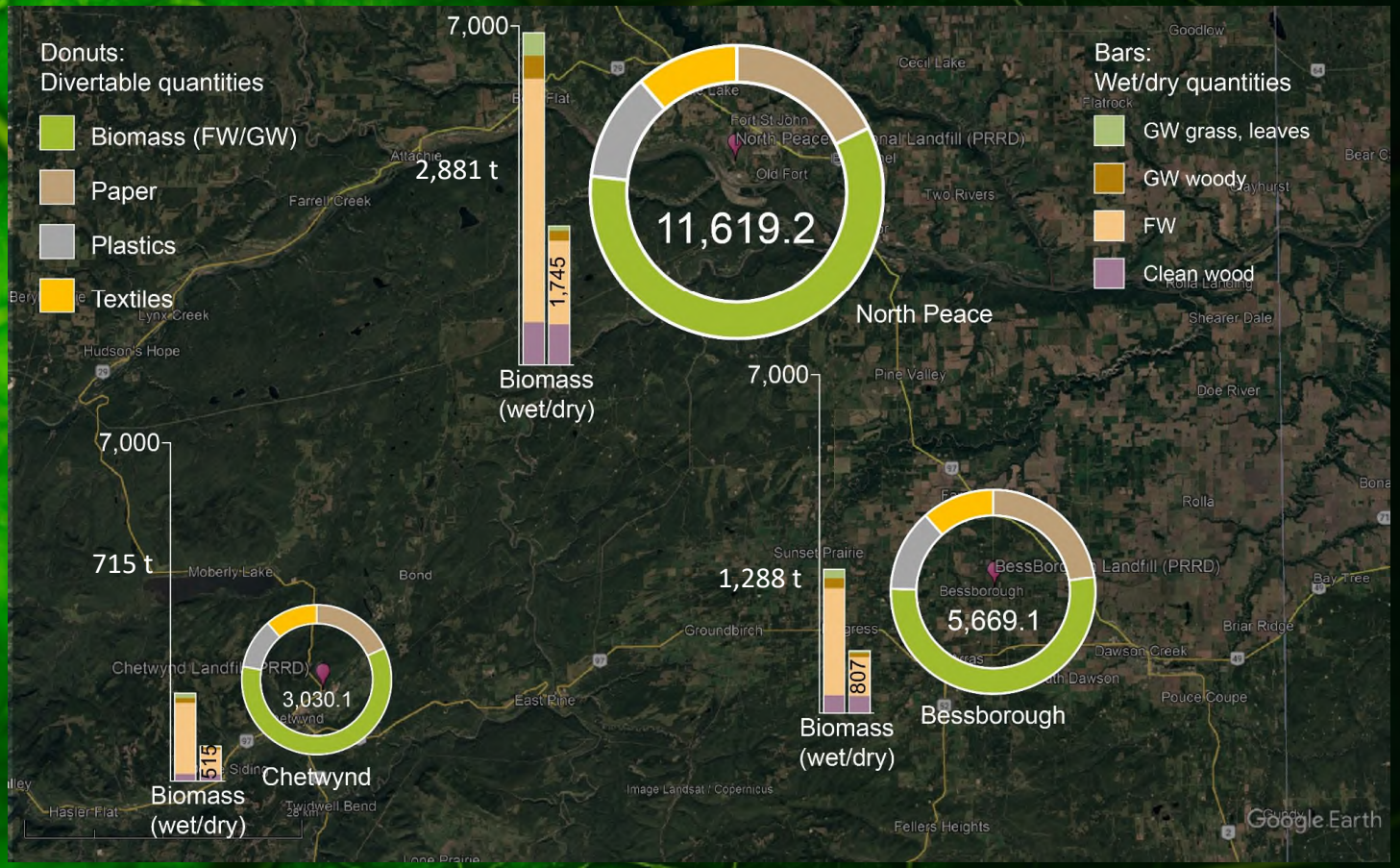
- 3 temperature zones, variable reaction speeds and times
  - Allows for more complete breakdown of organics
- 99% purity activated carbon through a steam process
  - More complete reaction and higher purity than usual 95%
- Auger type of reactor
- Improved system of sealing from outside air
- No inert gases necessary

Fuel oil processing

- Venturi condenser (condenses oil, not steam)
- Incorporates Alfa Laval separator
  - Separates into light oil fraction and heavy mazut fraction (2-3%).
  - Mazut may be reprocessed.

Information from the Magnum Group International posted business plan.

Landfill divertable feedstocks



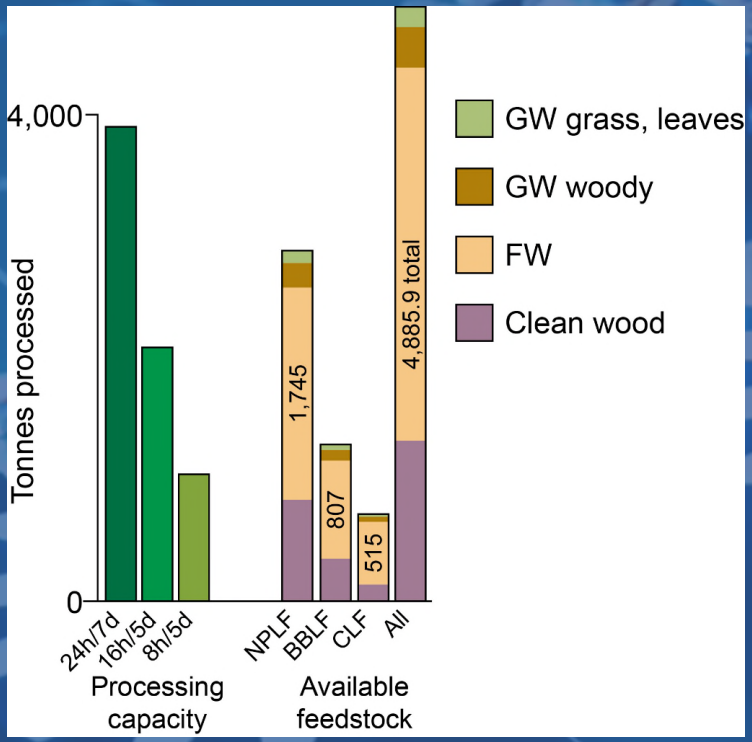
Assumptions:

- 90% of compostable organics:
  - Food waste (FW)
  - Green waste (GW; yard and garden)
- 80% of paper waste
- 30-80% of plastics
- 90% of textiles (synthetic and natural)

Pyrolysis is flexible and may be switched over to use other waste types.

Need: ~1,043 t dry minimum for 8h/day, 5 d/week.

Sub-regional operating scenarios

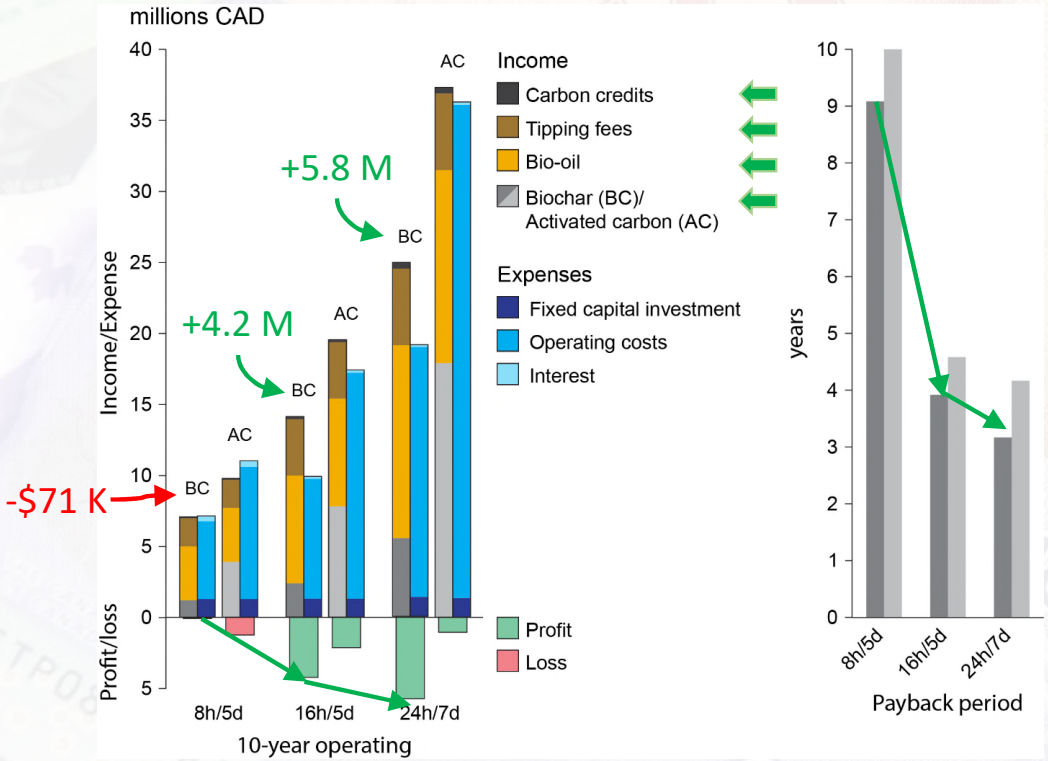


	Operating	Tonnage wet	Tonnage dry
1	8h/5d	3,200	1,043
2	16h/5d	6,400	2,086
3	24h/7d	~12,000	~3,900

- NPLF receives enough FW/GW to fulfill scenario 1 & 2 capacity.
- BBLF receives enough FW/GW to only fulfill scenario 1 capacity.
- CLF does not receive enough to fulfill any scenario capacity.

Consequence: Financial viability concerns, additional transportation costs, alternative sources of feedstock.

Sub-regional: Financial outlook



- Value of biochar (BC) $400/t, activated carbon (AC) $2,000/t.
- Oil/wax: $1.10/L (greater risk)

- Operating 8h/5d week is borderline breakeven-assumes enough feedstock available at the CLF (not the case through landfill diversion alone).

- Important need: Establish a market

Chemical upgrading of BC → AC
- Costly due to price of chemicals.
- Large environmental impact (CO_2e).

Assumptions: Amortization is 10 years; 6% interest, applied monthly; 50% of profits (if any) used to pay down principal. Inflation applied at 2.5%; fixed income rates for all sources.

Sub-regional financial outlook

Key concerns:

- Relies on a pyrolysis oil value of $1.10/L.
  - Unrefined value of oils/waxes, liquid: $0.55/L.
  - Retail for wood vinegar much greater (not included).
- Basic "pilot scale" setup does not allow for upgrading bio-oils/waxes or other liquids without large financial (and environmental) impact.

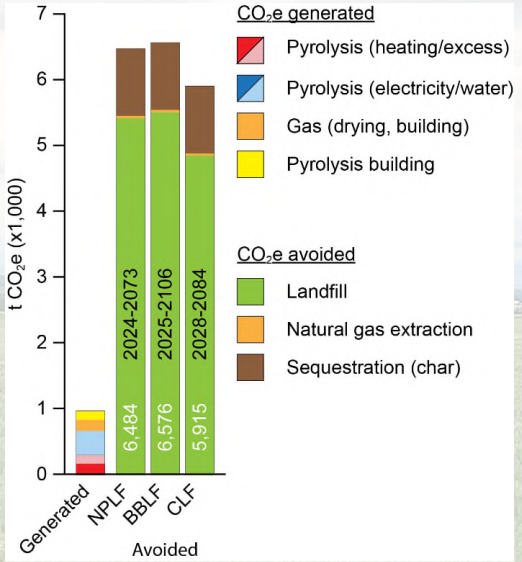
Biochar only min. cost for breakeven original scenario

	Scenario	CAD/t
1	8h/5d	$1,700
2	16h/5d	$1,000
3	24h/7d	$980

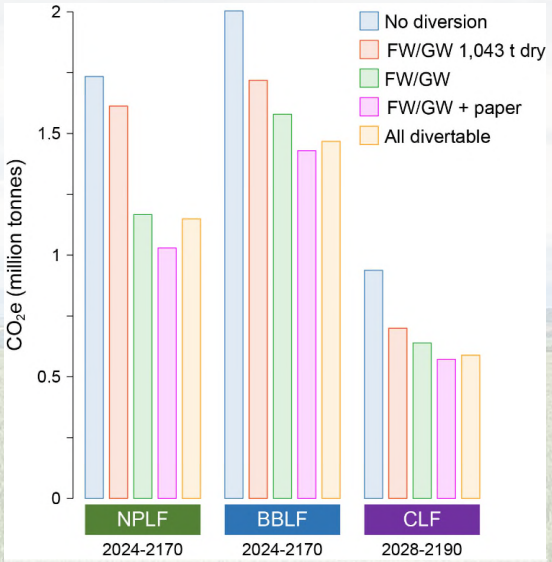
Recommended selling price: **$1,200-$1,300**/t min.

Scenario	Start-up time	Products			Operating costs /h			Profit (less start-up)
		Biochar per t	Biochar rate increase	Bio-oil /L	Operator	Plant manager	Book-keeper (PT)	
Original 1	6 mo	$400	0%	$1.10	$30	$40	$28	-$71,000
Original 2	6 mo	$400	0%	$0	$30	$40	$28	-$3,918,000
Option 1	3 mo	$1,200	2%	$0.55	$27	$35	$28	$1,437,000
Option 2	3 mo	$1,200	2%	$0	$30	$0	$28	$265,000

Sub-regional: Environmental outlook

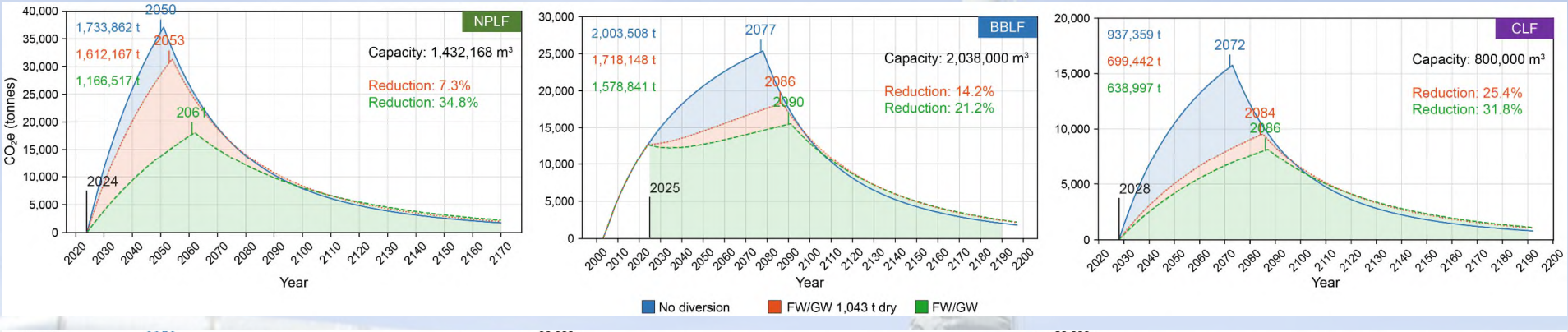


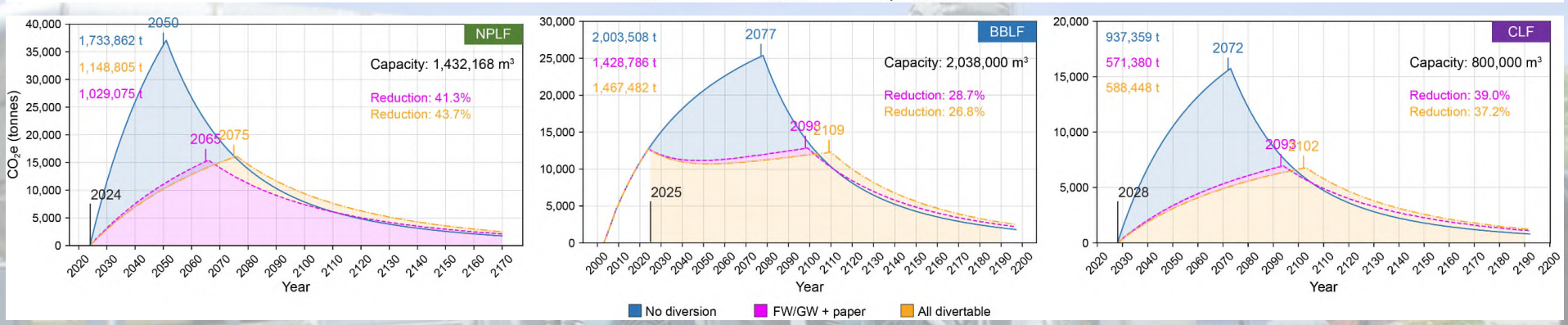
- CO_2e generated dwarfed by CO_2e avoided.



- FW/GW greatest source of CO_2e (highly decomposable).

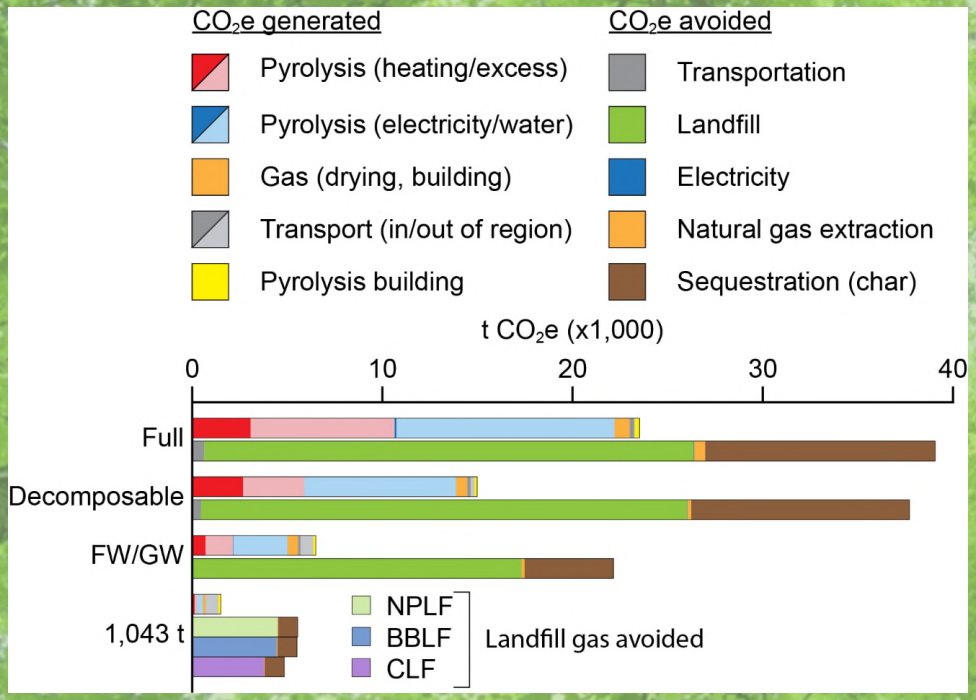
* *All divertable* slightly higher because of increased landfill capacity.





LF	Original	FW/GW		1,043 t		FW/GW+paper		All	
	Close	Close	Extend	Close	Extend	Close	Extend	Close	Extend
NPLF	2050	2061	+11	2053	+3	2065	+15	2075	+25
BBLF	2077	2090	+13	2086	+9	2098	+21	2109	+32
CLF	2072	2086	+14	2084	+12	2093	+21	2102	+30

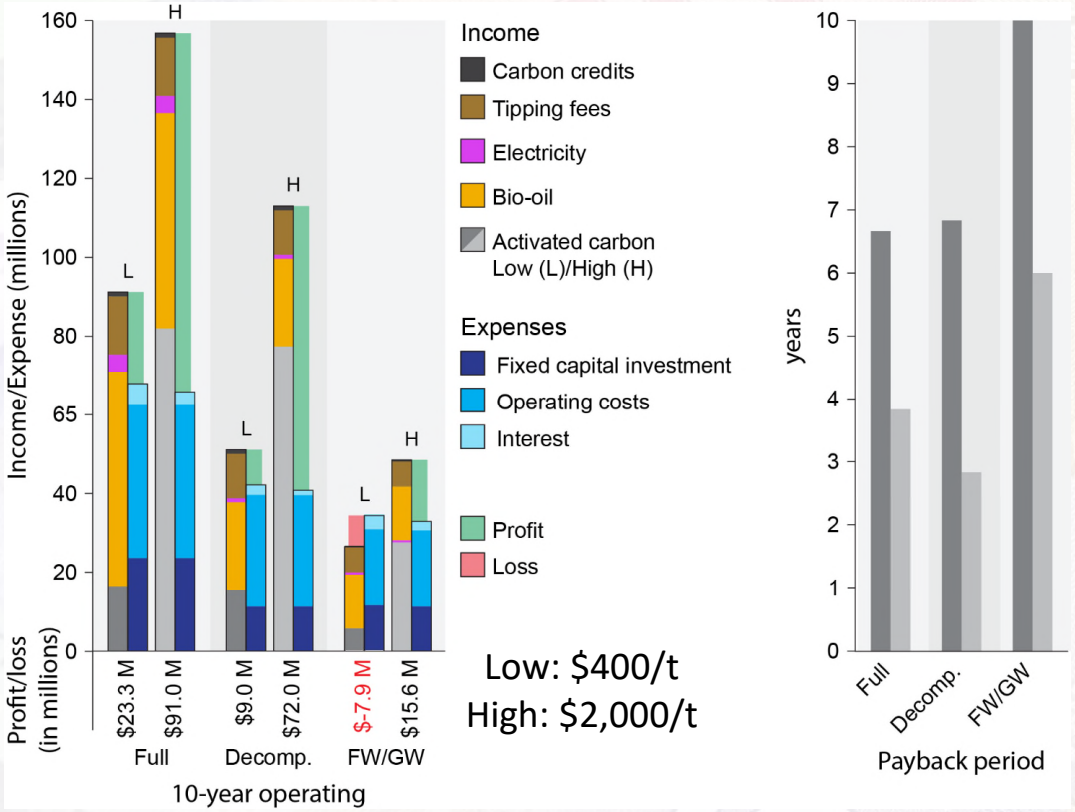
Regional CO_2e reduction



- Regional scenarios use the ATS-1000, which uses steam for biochar upgrading; therefore, greater water consumption.
- May be a possibility to reduce water consumption through cleaning/recirculation.

- LFG CO_2e reduction much greater than CO_2e produced by pyrolysis.
  - *Full* scenario targets oil from plastics.
  - Potential to capture CO_2 from pyrolysis to reduce output even further.
- Transport a minor component.
- Water usage is high; does not include treatment.
  - Recycling of plastics through mechanical means also very high and energy intensive.

Regional scale solution



Low: $400/t
High: $2,000/t

Assumes high conversion rate of biochar to upgraded biochar/activated carbon.

At 65% conversion:

Scenario	Profit/loss (millions)	
	Low	High
Full	$17.1	$61.6
Decomp.	$3.0	$44.8
FW/GW	-9.9	$5.3

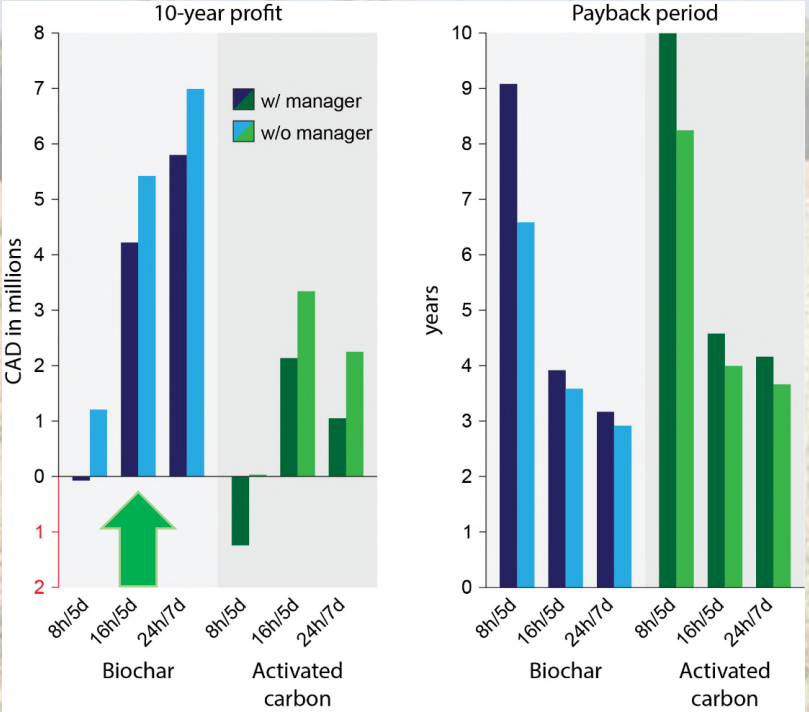
Scenario	Payback	
	Low	High
Full	7y 3m	4y 8m
Decomp.	8y 1m	3y 9m
FW/GW	10 years	7y 11m

Min. selling price of biochar if oil is $0.55/L

Scenario	Price
Full	$600
Decomposable	$525
FW/GW	$1,525

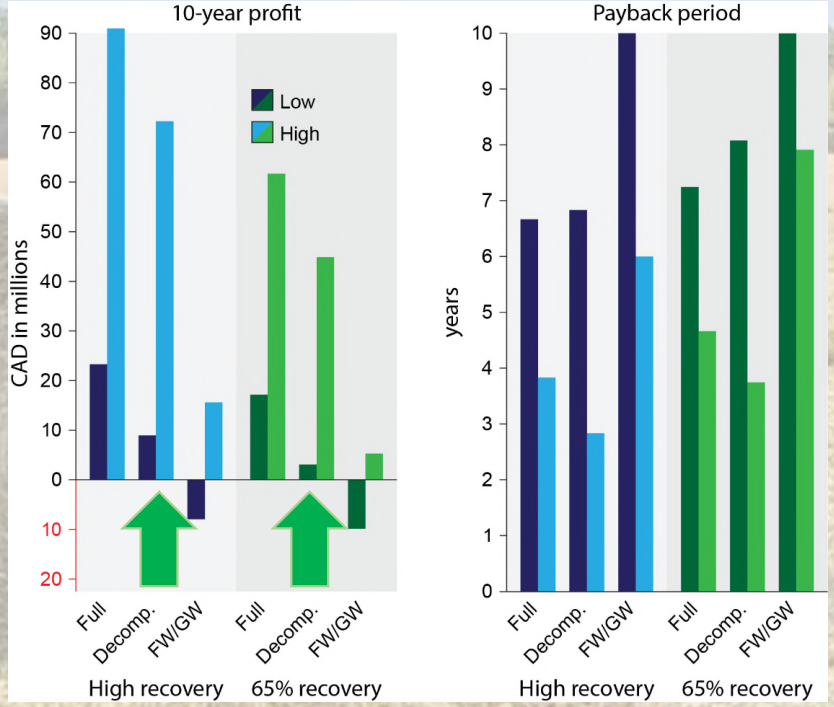
Financial summary

Sub-regional scale



- Biochar between 8-16 h/day.
- Minimal staff.

Regional scale



- *Decomp.* scenario lowest risk, good returns.
- Scenarios use full complement of staff.

Summary

Sub-regional scale

Pros:

- Small-scale, minimal capital, minimal employees.
- Logistically simpler.

Cons:

- Low volume, sensitive to fluctuations.
- Requires high price for biochar.
- Biochar of unknown quality, “off the shelf” unit.
- Cost of upgrading to activated carbon cost-prohibitive, environmentally unfriendly.

Regional scale

Pros:

- Potentially excellent returns for upgraded biochar and oils.
  - Complete solution.
- Significant diversion of landfill waste, landfill lifespan extension.

Cons:

- Much greater capital required.
- Logistically challenging:
  - Obtaining feedstocks
  - Transportation
  - Storage

Conclusions

Environment

- Reduced landfilling.
  - ↑ landfill lifespan.
- Significant CO_2e reduction at *all scales*.
- Carbon sequestration.
- FW/GW removal most impactful.

Financial

<u>Economy of scale</u>

- Sub-regional: >8h/day, 5 day/week
  - FW/GW feedstock:
  - NPLF>BBLF>CLF
- Regional:
  - Continuous, decomposable materials.

Marketing

<u>Find a market</u>

- Focus on bio-char, $1,200/t minimum.
- Regionally, add oil $0.55/L min.
- Wood vinegar may be marketable.

Recommendations

Sub-regional scale

- Location: BBLF or NPLF based on feedstock modeled.
- Restrict operation to two operators.
- Operate as closely to 16h/5d per week as possible, or more.

Regional scale

- Location: BBLF.
- Cost can be further reduced by reducing no. of employees.
- Target FW/GW and paper, including ICI, TS, and CCR.
  - Decomposable scenario

Moving forward

Establish market for biochar and bio-oils (wood vinegar?)

Environmental approval

Funding

Sub-regional:

- Small, “pilot-scale” implies research-sized unit; collaboration with research institute.
- Up to $1.5-$3 million investment.

Regional:

- Green bonds, environmentally-oriented funds.
- $13-$25 million range, depending on scale.
- Joint venture, “lease-to-own”.


thank you
danke
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ngiyabonga
teşekkür ederim
gracias
tapadh leat
спасибо
bedankt
dziękuję
obrigado
hvala
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Questions?

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