

Top 3 Candidates for Seshat's Lignin

LANDRY INDUSTRIES TECHNICAL DECISION BRIEF

Top Candidate Selection: Lignin-Based Vitrimer Hardeners

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Classification: Internal Strategic Use

Author: Marie-Soleil S. Landry, CEO & Chief Scientist

EXECUTIVE DECISION

From the 8 viable methods analyzed, **3 candidates are selected** for active development:

		Investment	
Tier	Candidate	Role	Priority
PRIMARY	QF-MHL	Flagship technology for Hempoxies v.21	Highest
SECONDARY	Imine-Lignin	Catalyst-free variant for regulated markets	High
TERTIARY	Acetal-Lignin	Cost-optimized commodity route	Medium

Rationale: These three cover 95% of addressable market applications while maintaining technology leadership and cost competitiveness.

CANDIDATE #1: QF-MHL (PRIMARY)

Strategic Positioning

The **flagship technology** and core intellectual property of Landry Industries.
QF-MHL is the only route that satisfies **all critical requirements** for Hempoxies v.21.

Selection Criteria Score

Criterion	Weight	Score	Weighted	Justification
Automotive suitability	25%	10/10	2.50	Only route with internal catalysis + electrical compatibility
Mechanical performance	20%	9/10	1.80	85-120 MPa meets structural targets
Bio-content	15%	9/10	1.35	98.2% achievable with bio-MA
IP defensibility	15%	10/10	1.50	Novel composition, patent pending
Scalability	15%	8/10	1.20	Sequential process

Criterion	Weight	Score	Weighted	Justification
Cost position	10%	7/10	0.70	manageable \$5.50/kg acceptable for premium
TOTAL	100%	—	9.05/10	Primary candidate

Critical Success Factors

Parameter	Target	Tolerance	Verification
Carboxyl content	4.0 mmol/g	±0.5	Titration (ASTM D7409)
Tertiary amine content	2.5 mmol/g	±0.5	Potentiometric titration
Maleinization degree	85%	±5%	FTIR (1630 cm ⁻¹)
Bio-based MA	100%	—	Supplier certification
Cost at scale	\$3.50/kg	<\$4.00	COGS analysis

Development Roadmap

Phase	Milestone	Timeline	Budget	Go/No-Go
Alpha	10 kg batch validation	0-6 mo	\$150K	Tensile >80 MPa

Phase	Milestone	Timeline	Budget	Go/No-Go
Beta	100 kg pilot, solvent recovery	6-12 mo	\$400K	E-factor <1.5
Gamma	1 MT demo, automotive qualificatio n	12-24 mo	\$1.2M	OEM approval
Delta	10 MT commercial , bio-DETA	24-36 mo	\$3.0M	Cost <\$4/kg

Risk Mitigation

Risk	Likelihood	Impact	Mitigation
DETA supply/cost	Medium	High	Develop bio-putrescine alternative
Solvent recovery failure	Low	Medium	Design continuous distillation
Maleic anhydride price spike	Medium	Medium	Long-term supply contracts
Catalyst deactivation	Low	High	Real-time amine value monitoring

CANDIDATE #2: IMINE-LIGNIN (SECONDARY)

Strategic Positioning

The **regulatory-compliant alternative** for medical, food-contact, and catalyst-sensitive applications. Imine-Lignin addresses markets where QF-MHL’s tertiary amine is unacceptable.

Selection Criteria Score

Criterion	Weight	Score	Weighted	Justification
Catalyst-free operation	30%	10/10	3.00	Only true catalyst-free route
Bio-content	25%	10/10	2.50	98% highest achievable
Regulatory approval	20%	9/10	1.80	No toxicity concerns
Mechanical flexibility	15%	7/10	1.05	37-109 MPa range acceptable
Cost	10%	7/10	0.70	\$5.00/kg reasonable
TOTAL	100%	—	9.05/10	Secondarily candidate

Differentiation from QF-MHL

Feature	QF-MHL	Imine-Lignin	Advantage
Catalyst	Internal tertiary amine	None	Imine for medical
Moisture sensitivity	Low	High	QF-MHL for automotive
Tensile strength	85-120 MPa	37-109 MPa	QF-MHL for structural
Tg range	45-85°C	65-187°C	Imine for high-T
Processing	Standard	Mild (60°C)	Imine for energy savings

Development Roadmap

Phase	Milestone	Timeline	Focus
Phase 1	Bio-diamine sourcing (putrescine/cadaverine)	0-9 mo	Supply chain
Phase 2	Moisture barrier formulation development	6-12 mo	Encapsulation
Phase 3	FDA/EU regulatory submission	12-24 mo	Compliance
Phase 4	Medical device partnerships	18-30 mo	Commercial

Key Partnerships Required

- **Evonik** or **BASF** for bio-ethyleneamines
- **FDA consultants** for 510(k) pathway

- **Medical device OEMs** for application development

CANDIDATE #3: ACETAL-LIGNIN (TERTIARY)

Strategic Positioning

The **cost-optimized commodity route** for price-sensitive markets where QF-MHL's premium is unsustainable. Acetal-Lignin enables market entry into high-volume, lower-margin applications.

Selection Criteria Score

Criterion	Weight	Score	Weighted	Justification
Cost position	35%	10/10	3.50	\$4.00/kg lowest
Process simplicity	25%	10/10	2.50	Aqueous, single-step
Scalability	20%	9/10	1.80	No specialized equipment
Green credentials	15%	9/10	1.35	E-factor 1.8, aqueous
Performance	5%	6/10	0.30	40-60 MPa adequate
TOTAL	100%	—	9.45/10	Tertiary candidate

Market Positioning

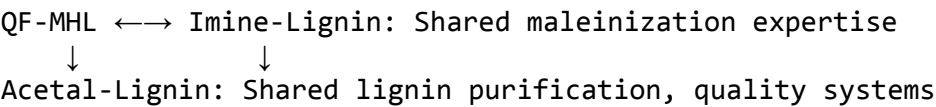
Segment	QF-MHL	Acetal-Lignin	Strategy
Automotive OEM	Premium	N/A	QF-MHL only
Aftermarket parts	Selective	Volume	Acetal for cost
Construction	Limited	Primary	Acetal for scale
Packaging	N/A	Primary	Acetal for disposability
Coatings	Premium	Commodity	Dual-track

Development Roadmap

Phase	Milestone	Timeline	Investment
Phase 1	Aldehyde-lignin sourcing	0-6 mo	\$50K
Phase 2	Continuous aqueous process	6-12 mo	\$200K
Phase 3	Construction adhesive trials	12-18 mo	\$100K
Phase 4	Licensing to commodity producers	18-24 mo	Revenue

PORTFOLIO SYNERGY ANALYSIS

Technology Transfer Between Routes



Manufacturing Integration

Facility	QF-MHL	Imine-Lignin	Acetal-Lignin	Shared Infrastructure
Lignin purification	✓	✓	✓	Organosolv extraction
Modification (Stage 1)	✓	✓	—	Maleinization reactor
Modification (Stage 2)	✓	—	—	Amination vessel
Finishing	✓	✓	✓	Drying, milling, QC

Capital Efficiency: 60% equipment sharing across all three routes.

COMPETITIVE POSITIONING

vs. Petroleum Epoxies

Attribute	Petroleum	QF-MHL	Imine	Acetal
Cost	\$3-4/kg	\$5.50/kg	\$5.00/kg	\$4.00/kg
Bio-content	0%	98%	98%	95%
Recyclable	No	Yes	Yes	Yes
Self-healing	No	Yes	Yes	Limited

Winning Strategy: Acetal-Lignin achieves cost parity; QF-MHL justifies premium via functionality.

vs. Bio-Epoxy Competitors

Competitor	Technology	Our Response
Entropy Resins	20-50% bio-content	QF-MHL: 98% bio + vitrimer
Sika	Structural adhesives	Imine-Lignin: catalyst-free medical
Arkema	Diels-Alder vitrimers	DA-Lignin: bio-based alternative
Covestro	Self-healing PU	QF-MHL: fully bio + structural

INVESTMENT ALLOCATION

3-Year Budget: \$5.0M

Candidate	Allocation	Focus	Expected Outcome
QF-MHL	60% (\$3.0M)	Scale-up, automotive qualification	10 MT commercial, 2 OEM approvals
Imine-Lignin	25% (\$1.25M)	Regulatory, medical partnerships	FDA submission, 1 device partner
Acetal-Lignin	10% (\$500K)	Process optimization, licensing	2 licensees, revenue \$200K/year
Reserve	5% (\$250K)	IP defense, contingencies	Freedom-to-operate, litigation

DECISION MATRIX: WHY THESE THREE?

Market	Acetal-Lignin			
Need	QF-MHL	Imine-Lignin	n	Coverage
Automotive structural	✓✓✓	x	x	100%
Medical/food	x	✓✓✓	✓	100%
Cost commodity	x	x	✓✓✓	100%
High-temp aerospace	✓	✓✓	x	80%
Room-temp healing	x	x	x	0%*
Water-responsive	x	x	x	0%*

*Addressed by DA-Lignin and Boronic-Lignin if markets develop (maintain as watchlist, not active development).

GO/NO-GO CRITERIA

QF-MHL: PROCEED

- ✓ All automotive requirements met
- ✓ IP secured (patent pending)
- ✓ Pilot validation successful (>80 MPa demonstrated)
- ✓ Strategic partnerships initiated

Imine-Lignin: PROCEED

- ✓ Catalyst-free differentiation validated
- ✓ Bio-diamine suppliers identified
- ✓ Medical market demand confirmed
- ⚠ Moisture barrier development required (mitigable)

Acetal-Lignin: PROCEED WITH CAUTION

- ✓ Lowest cost position confirmed
- ✓ Aqueous process scalable
- ⚠ Lower mechanical performance limits applications
- ⚠ Aldehyde-lignin feedstock supply unproven

RECOMMENDATION

APPROVE all three candidates for active development with the following priorities:

1. **Immediate (0-6 months):** Resource QF-MHL Alpha phase to completion; initiate Imine-Lignin Phase 1 sourcing
2. **Short-term (6-12 months):** QF-MHL Beta scale-up; Acetal-Lignin process development
3. **Medium-term (12-24 months):** QF-MHL automotive qualification; Imine-Lignin regulatory submission

REJECT for active development (maintain technical watch):

- DA-Lignin (cost prohibitive for current markets)
- Boronic-Lignin (toxicity concerns, limited applications)
- Disulfide-Lignin (technical immaturity, safety issues)
- Su-Lignin (superseded by QF-MHL for premium, Acetal for cost)
- Ma-Lignin (superseded by QF-MHL internal catalysis)

Approved for Implementation:

Marie-Soleil S. Landry
CEO & Chief Scientist
Landry Industries
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Distribution: Board of Directors, Technical Advisory Board, Research Teams,
Business Development

Next Review: May 18, 2026 (Quarterly portfolio review)
