Three Small Themes on Large-Scale Carbon Materials

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Our experience with carbon products at large scale:

A successful new carbon product must solve a specific problem, and solve it better than the customer's other choices

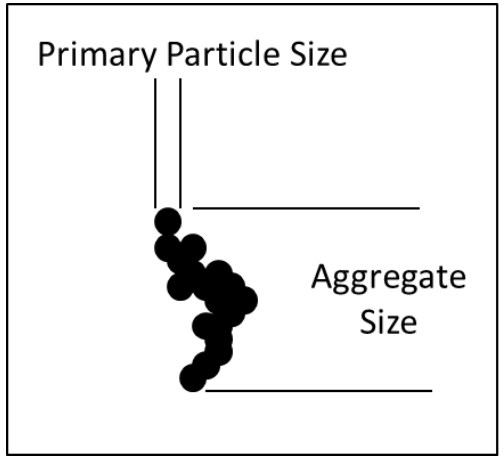
The "Experience Curve" usually governs the relationship between volume and price (or, volume and world's capacity to absorb it)

A successful byproduct carbon will need to be safe, and if a filler, will need to be "non-dys-functional"

An example large-volume carbon material with properties controlled to provide specific change in performance:

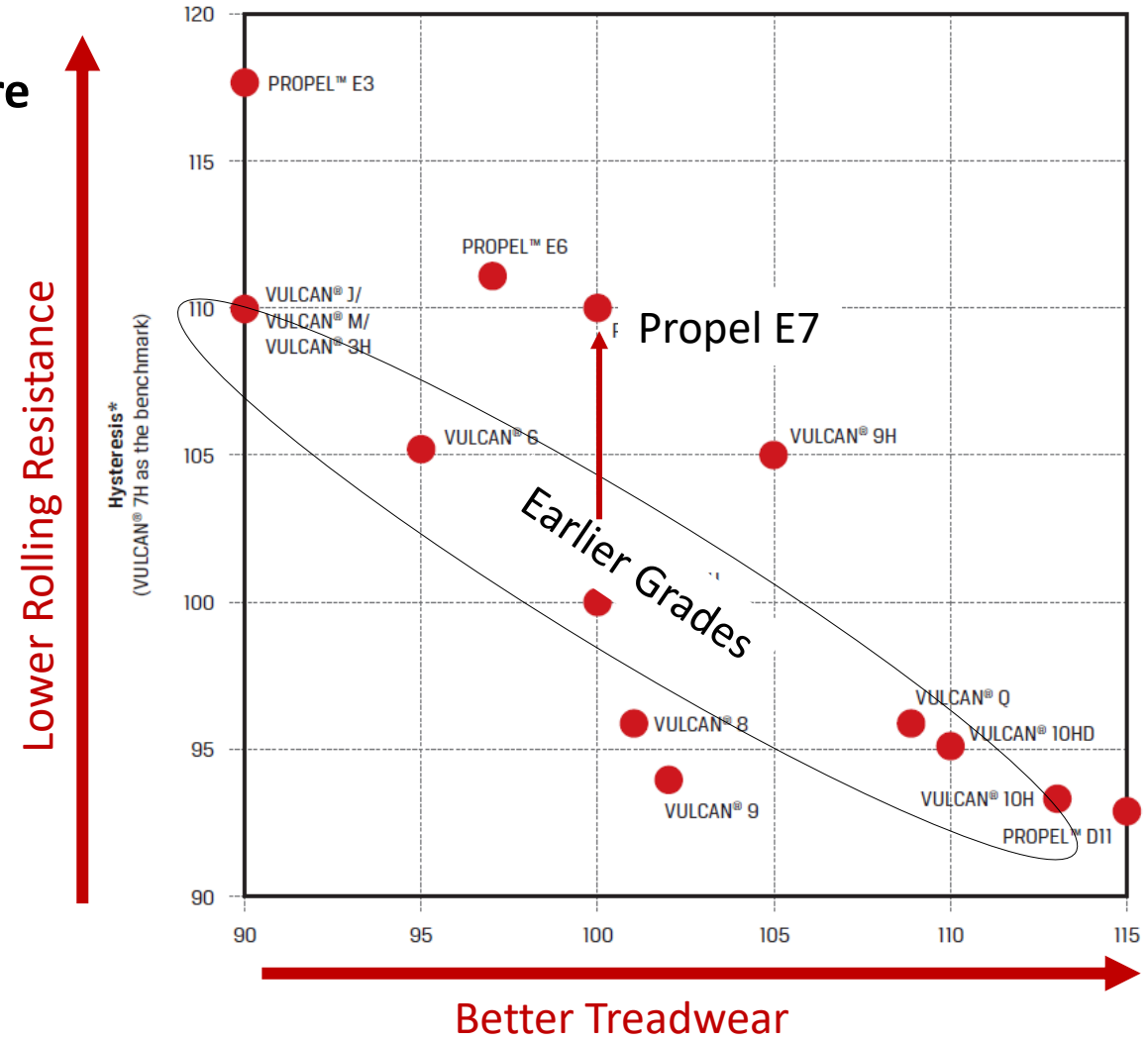
PROPEL E7

Improve rolling resistance at constant treadwear, truck tire



Rolling resistance → particle size, aggregate size, ASD
Treadwear → particle size, ASD
Useability → aggregate size, pellet dust, grit
Compatibility → surface chemistry

>6 independent particle properties to control



A new carbon will not naturally be independently controllable in many properties

Successful new materials usually require a lot of detailed application knowledge

This knowledge takes many years to build.

Core businesses

Business development

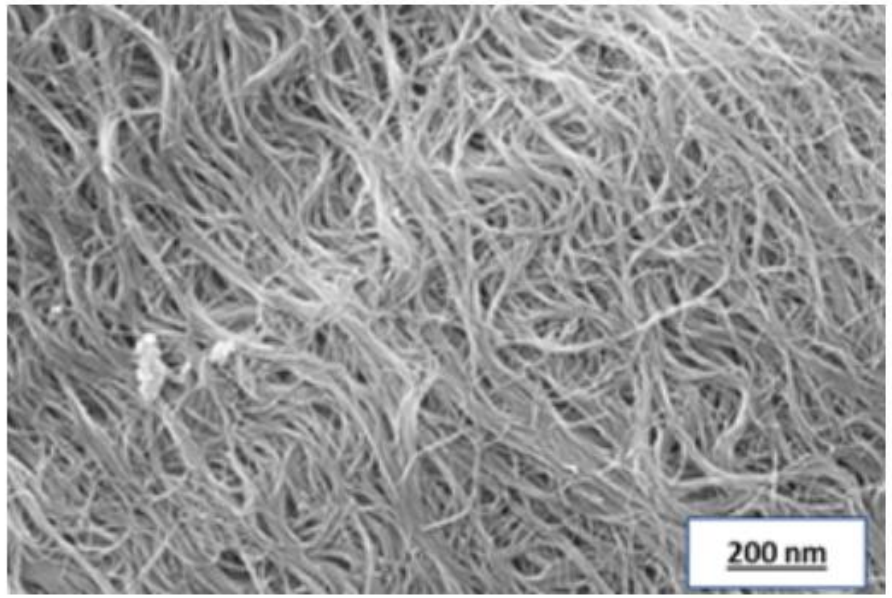
Scouting (problems)

Competencies/RD
- Process
- Applications
- Particle

(3M)

Strong applications knowledge lets us identify more advanced carbons, with better or complimentary functions

ATHLOS Carbon Nanostructures



Conductivity with better processability

EMI shielding

Strength at very low loading

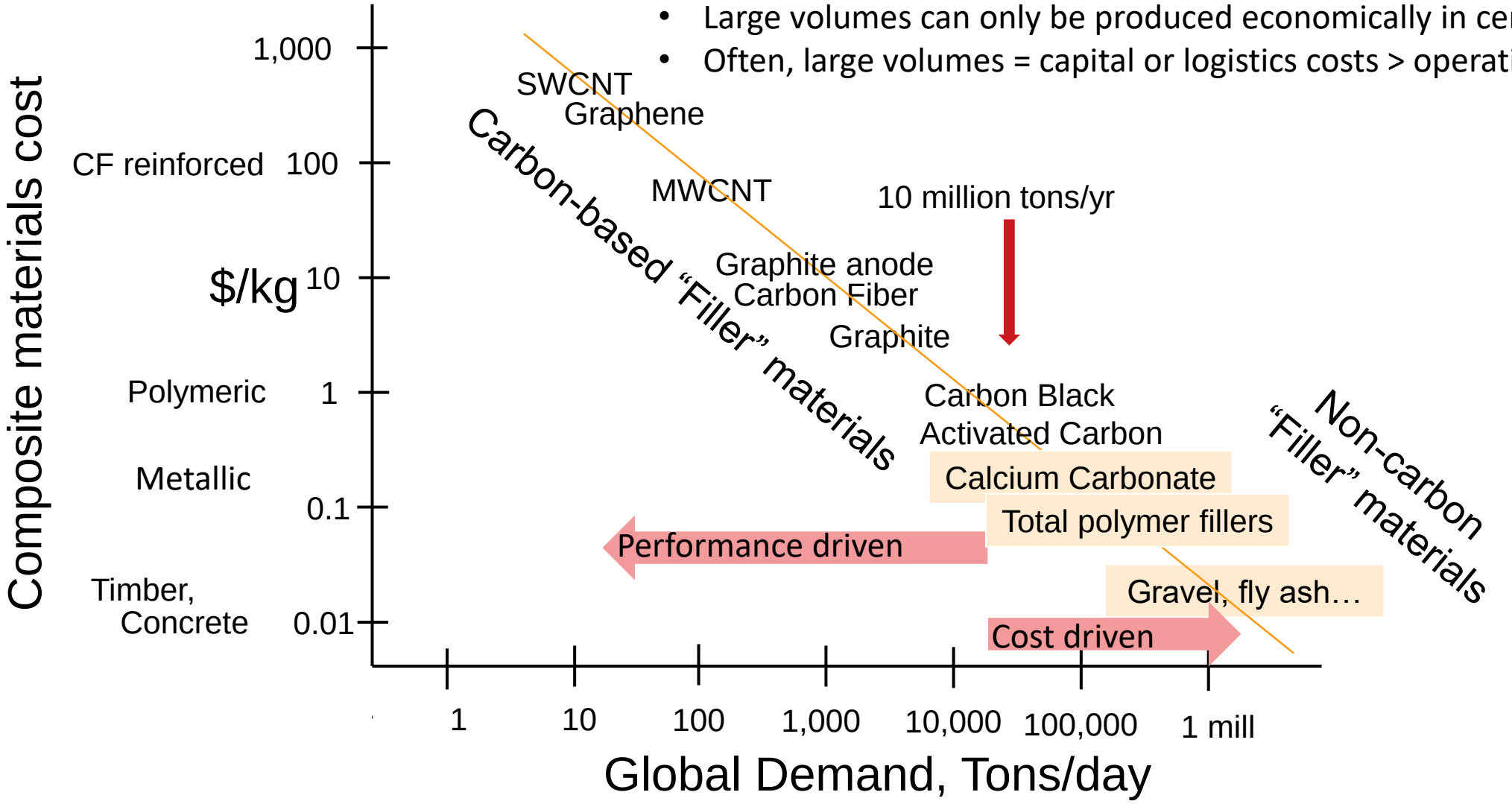
Benign exposure profile

ENERMAX Carbon Nanotubes

MWCNTs and Cabot conductive carbon blacks can work well together in LIB cathodes.

The experience curve shows what volumes of material can go with what costs

- Large volume can only cost so much
- Large volumes can only be produced economically in certain ways
- Often, large volumes = capital or logistics costs > operating costs

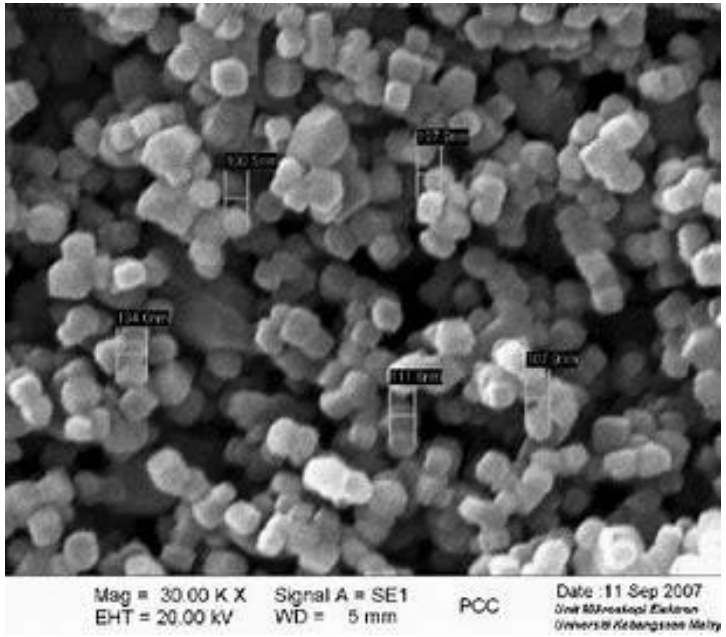


Side note: capital costs can be *dominant* at the large scales (HX surface area, gas volumes)

A byproduct to be used as filler must displace something much more expensive, without completely ruining properties (non-dysfunctional)

Displace expensive functional matrix

- Cement
- Polymers
- Metal
- Ceramic



Examples: Calcium carbonate, kaolin (Al-Si-O), talc (Mg-Si-O)

Minimally functional carbon particles must combine low cost with certain properties

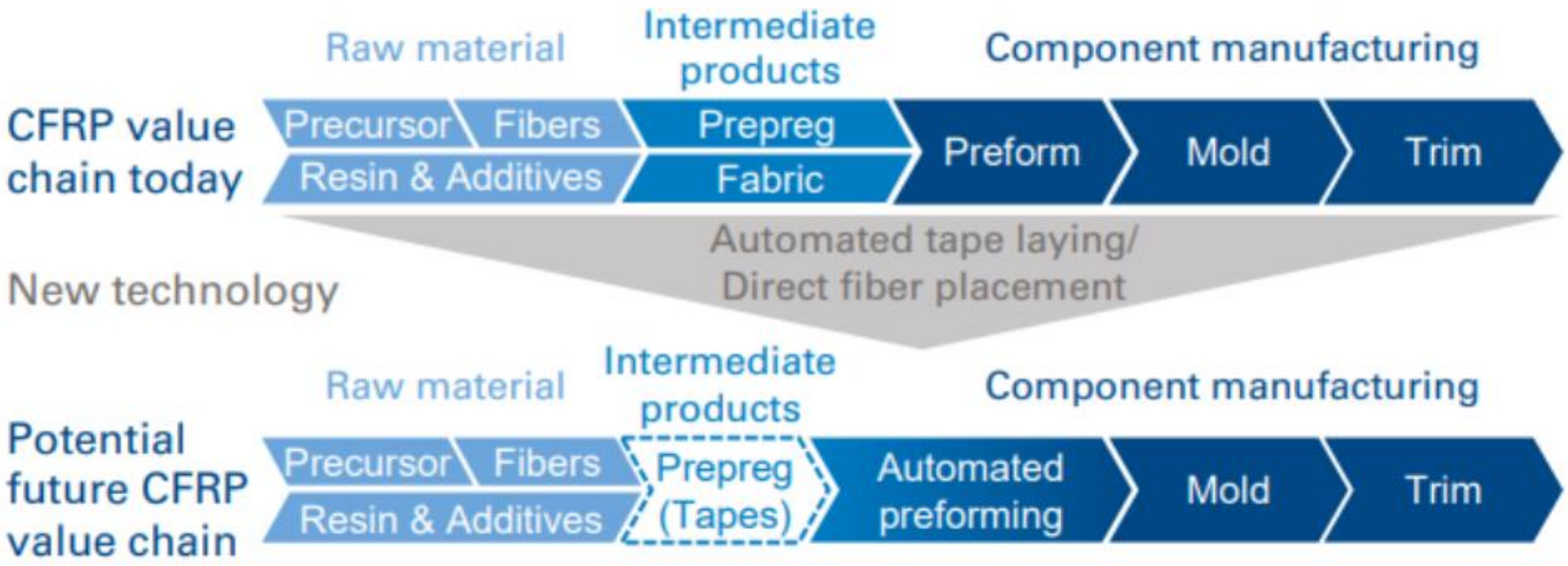
Must haves in general

- Low cost near $100/ton
- Safe (required even for landfill)
  - *Metals* benign/low
  - Organics benign/low
  - Morphology ~~asbestos~~…
- Easy to work with

Mechanical properties require

- Size 0.1-100 microns, more preferably 1-10 microns
  - Small gives dispersion/rheology issues
  - Large degrades mechanical properties
- Shape: equiaxed easiest to deal with
- Dispersible to high loadings (~50%)

The implied challenge is to find a way to “skip the particle and go direct to the article”



Source: Arthur D. Little analysis

- Go past particles in a single process
  - Fibers
  - Layers
  - Sheets
  - Composites
- How to do this at realistic capital costs? (no “ALD for road construction” projects)