Biofuels : Technology meets Strategy

Non-Food Oil Alternatives to Diesel Fuel

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Biofuels Technology Development Drivers

- **Greenhouse gas reduction**
  - Maximum potential of the whole supply chain
- **Sustainable Feedstock**
  - Agreed criteria for feedstock sustainability
- **Cost and Energy Efficiency**
  - Large and small scale solutions
  - Efficient at all stages from “earth to engine”
- **Maintained or enhanced performance in application**
  - No reduction in fuel efficiency
  - Improved emissions quality
- **Technology Selection**
  - Performance Driven
  - Market forces & economics to determine winner
  - Legislation only where necessary

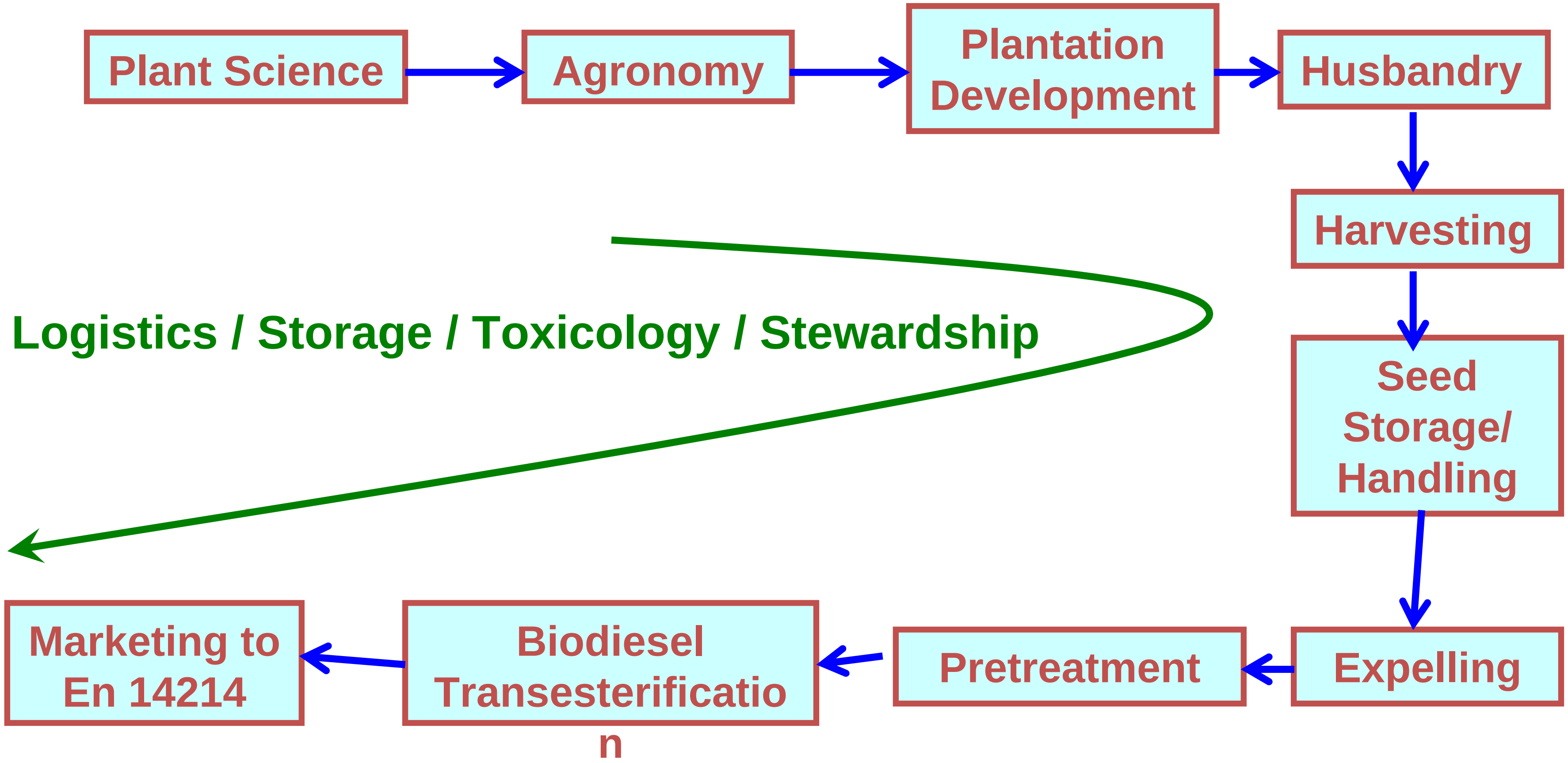
First Generation Biofuel Technology

- **Primarily based on existing food crops**
  - Wheat, maize and sugar cane for bioethanol
  - Rape, soy and palm oils for FAME biodiesel
- **Produced using simple established technology**
  - Fermentation for bioethanol
  - Methanolysis (transesterification) for biodiesel
- **Utilise existing supply and purification chains**
- **Detail engine design determines performance**
- **Conflicting consumer demands lead naturally to the current food versus fuel debate**

Second Generation Fuel Crops

- **Specific parameters to avoid the food-fuel and rainforest destruction debates**
  - **Need to grow on unproductive land with low biodiversity**
    - No rain forest destruction
    - Provide local employment
    - Generally poor quality soils in semi-arid conditions
    - Minimum irrigation requirement
  - **Should be high yielding (te of fuel/year per hectare)**
    - Vegetable oils – Triglycerides with FA carbon chain lengths of C12 to C20
    - Starch/sugars for bioethanol
    - Residual biomass for combustion
  - **Agronomy training as "non-food " normally implies toxic to humans.**
    - New supply chain requirement to avoid contamination

Supply Chain Development
Non-food oil crops



Agronomy

- **Most potential non-food oil plants grow wild at present**
  - Castor oil is main exception; jatropha development underway
- **Adaption for plantation growth**
  - Soil type variability
  - Climate (rainfall, temperature variation, no of cropping seasons)
  - Fertiliser/manure requirement
  - Spacing
  - Impact of pruning; potential for mechanical harvesting

Plant Breeding

- **Acquire Accessions to identify positive traits**
  - Establish breeding programmes
  - Natural selection possible from wide gene pool
  - Genetic modification by gene splitting not required.
- **Breeding Targets**
  - Maximise oil yield per hectare
  - Ensure equal ripening for quality control at harvest.
  - Modify triglyceride fatty acid profile
    - Good cold flow requires unsaturation
    - Polyunsaturation leads to poor oxidative stability
  - Eliminate toxic compounds
    - Rape originally toxic due to high levels of erucic acid
    - Selective breeding modified metabolic pathway; converted erucic to oleic acid

Non-Food Oil Crop Commercialisation

- **Crops under development include**
  - Jatropha
  - Pongamia
  - Neem
- **Tend to be trees or shrubs rather than annuals**
  - Long lead times to commercial cropping
- **Toxic nature varies**
  - Carcinogen promoters, sensitisers, ribose inhibiting proteins
  - Understanding toxicology important for all aspects of husbandry
  - Important consideration for Europe under REACH regulations
- **Scale up requirement takes non-food oils into new league**
  - Palm and soy oil >30 million tes/year; rape 18 million tes/year
  - Highest tonnage non-food oil is castor oil at < 1 million tes per year – ranked only 17th in world tonnage.

Supply Chain Technology Development

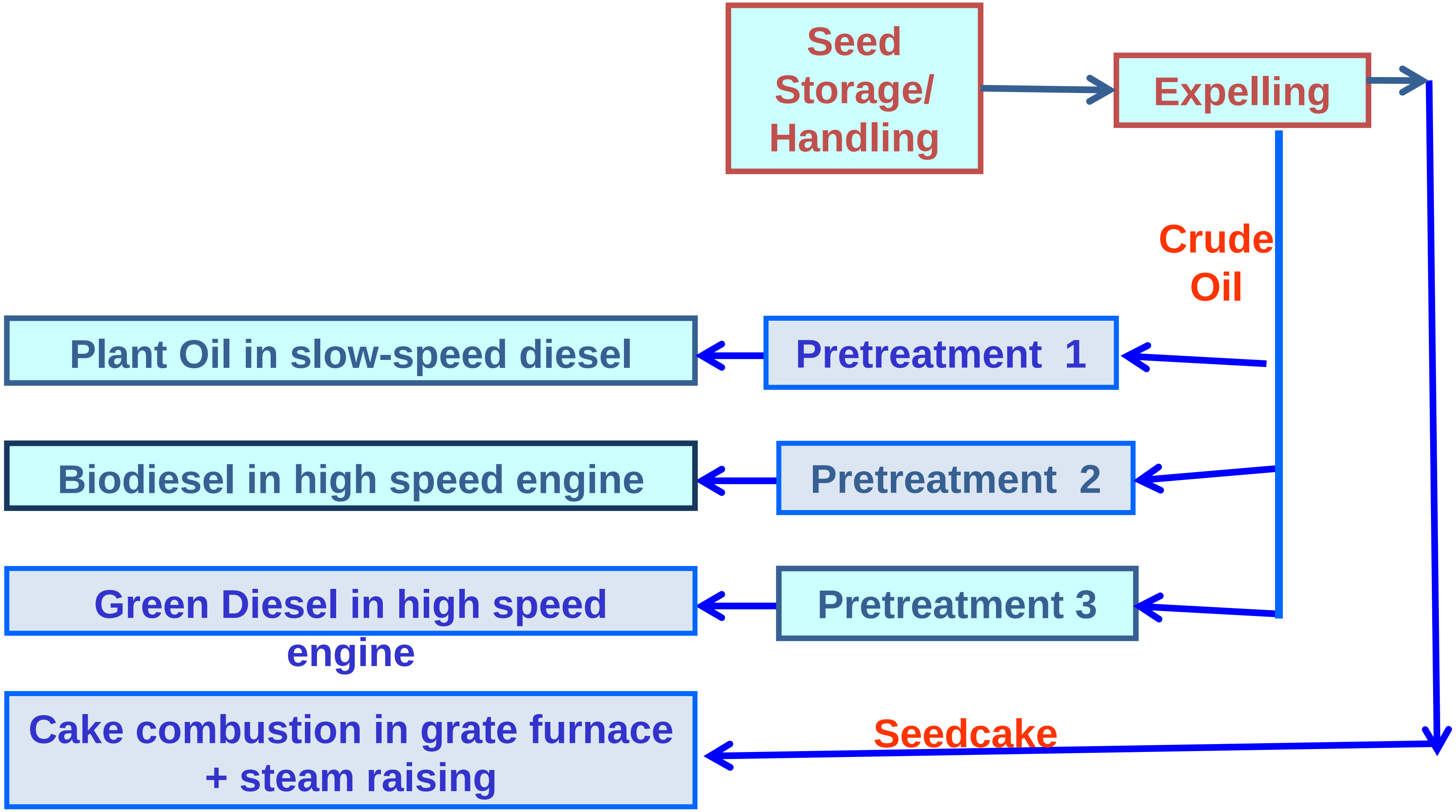
- **This has to be aligned to the end-use of the product**
  - Compression ignition engine invented by Rudolf Diesel in 1897 was demonstrated at the Paris Exhibition operating on peanut oil
  - Over 100 years of development on fossil mineral oils followed
  - Retrofitting a renewable product requires a detailed understanding of sophisticated engine technology
    - Manufacturer's designs vary
    - E.g. Common rail pressures now over 2000bar – very high shear kickback
    - Emission regulations met differently –EGR or SCR(urea)

- **Fatty acid methyl ester (FAME or classical biodiesel)**
  - Simple first generation technology that overcomes the major deficiencies of pure vegetable oils by conversion of a tri-ester to monoesters
    - Viscosity for pumping
    - Volatility for cold starting

Second Generation Diesel Production Technology

- **Tend to breakdown sustainable feedstocks into to simpler products and rebuild**
  - **Vegetable oil hydrosplitting/hydroisomerisation**
    - Commercialised as Neste NexBTL / UOP Ecofining processes
    - Slow uptake due to high hydrogen demand and high capital
  - **Syn Gas Manufacturer from biomass followed Fischer-Tropse molecule building**
    - Being developed by Shell as an extension of their GTL F-T process
- **Product is primarily paraffinic and hence similar to components in current En 590 ULS Diesel**
  - Process technology favoured by large oil majors
  - Large scale required for good economics hence high capital
  - Not suitable for application in areas where new crops are being grown

Pre-treatment technologies for oil have to vary with both application and diesel process technology



New fuels offer potential for improved engine technology

- **Homogeneous Charge Compression Ignition (HCCI)**
- **As distinct from:-**
  - HCSI – homogeneous charge spark ignition
    - – Classical spark ignition gasoline engine
  - SCCI – Stratified (heterogeneous) charge compression ignition
    - – Classical diesel engine

– **Fewer components in fuel could allow improved control**

– **Overcomes current environmental shortcomings**

  - Petrol engine – good emission quality but poor thermodynamic efficiency due to throttling losses.
  - Diesel engine – good efficiency but poorer emission quality

Thank You