Market Opportunities and Challenges Facing the Economically Viable Production of Renewable Chemicals in U.S. Biorefineries

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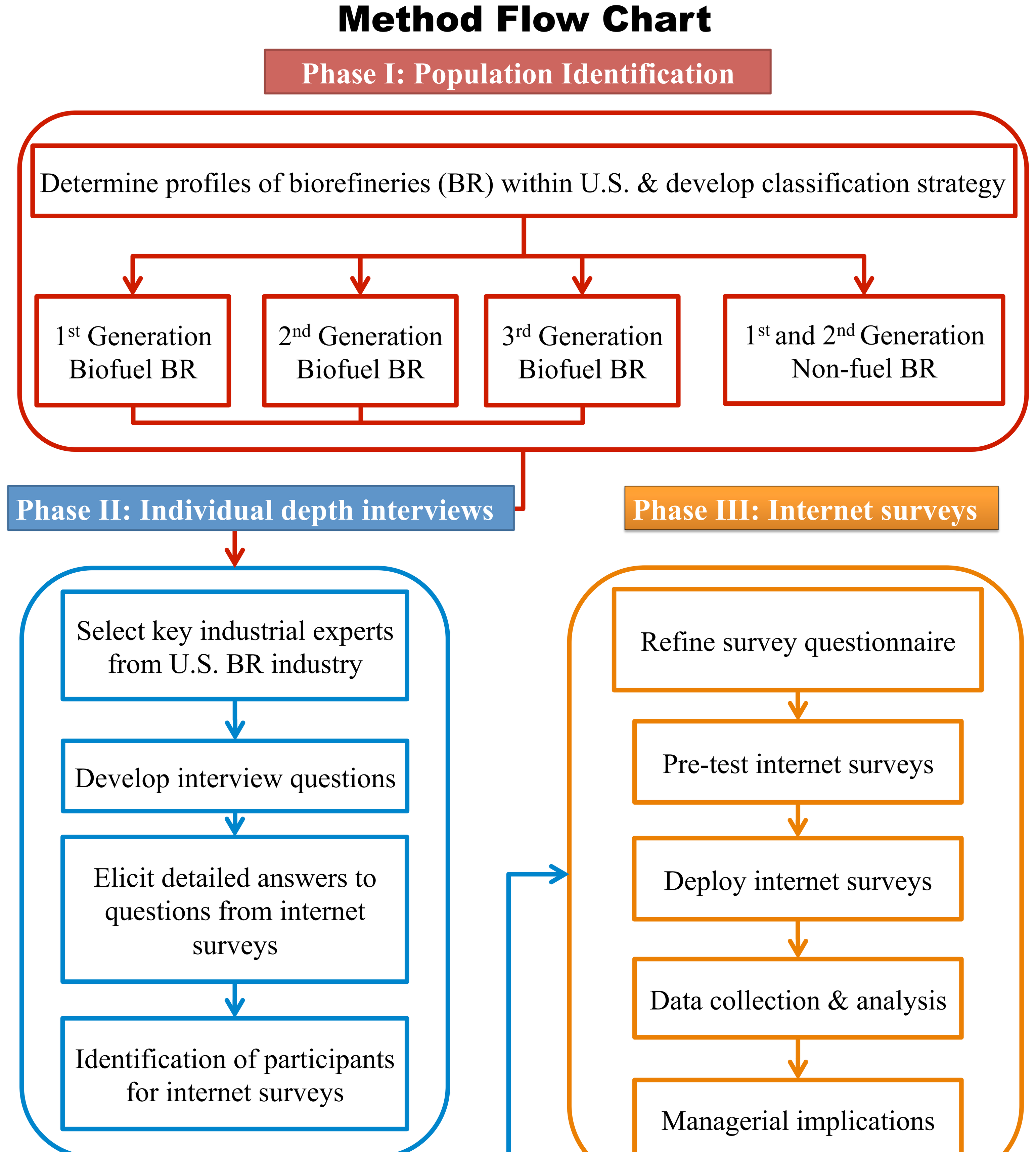
Introduction

Restricted by the current situation of the ethanol surplus problem and the "food-vs.-fuel" debate, biorefineries have been striving to diversify their product portfolios in order to enhance economic competitiveness of biorefineries (Babcock et al., 2011). During the past five years, research interests have been focused on building biorefineries with non-food based feedstocks (Sims et al., 2008). However, these advanced biofuel biorefineries are impeded by feedstock availability, technological sophistication, and capital investment (Fiorese, 2013; FitzPatrick et al., 2010). Others are trying to make full use of the raw material by producing value-added co-products with biofuels (de Jong et al., 2012). Specifically, some biorefineries (such as Gevo, Amyris, Cargill, etc.) are seeking to integrate the production of high-value renewable chemicals with low-value biofuels (Amidon et al., 2008; FitzPatrick et al., 2010). However, there is a long list of possible renewable chemicals that could be produced from biorefineries, and the production of renewable chemicals is dependent upon technological development, adequate facilities and downstream market demand (Bozell and Petersen, 2010; Himmel et al., 2007). Therefore, the main concern of this research is to understand the market opportunities and challenges facing the economically viable production of renewable chemicals.

Method Flow Chart



Top 22 Renewable Chemicals

(Bozell and Petersen, 2012; de Jong et al., 2012; Erickson, 2012; EuBP, 2013)

Groups	Renewable chemicals	Companies
Furans & derivatives	❑ Furfural ❑ Hydroxymethylfurfural (HMF) & Furan-2,5-dicaboxylic acid (FDCA)	❑ Avantium (Netherland)
Biohydrocarbons	❑ Iso-prene	❑ Amyris
	❑ Biohydrocarbons (long chain)	❑ Amyris, Dynamitic fuels, REII
	❑ Para-xylene	❑ GEVO, Anellotech, UOP, Virent
Organic acids & derivatives	❑ Lactic acid /polylactide (PLA)	❑ PURAC, NatureWorks, ECOSPAN,
	❑ Acrylic acid	❑ OPXBIO/DOW Chemical, ADM/BASF
	❑ Succinic acid and derivatives (1,4-Butanediol (BDO))	❑ BioAmber, Myriant, BASF/PURAC, Genomatica
	❑ 3-Hydroxypropanoic acid (3-HPA)	❑ Cargill
	❑ Levulinic aicd	❑ Avantium, Segetis
	❑ Acetic acid	❑ ZeaChem
Alcohols & derivatives	❑ Ethanol and derivatives (ethylene/ polyethylene)	❑ FKuR Plastics Corp. ❑ Braskem (Brazil)
	❑ Butanol/iso-butanol & derivatives (butadiene)	❑ GEVO, Butamax, Cobalt
	❑ Glycerol and derivatives (ethylene glycol, propylene glycol, 1,3-propanediol (PDO))	❑ Braskem (Brazil), Dupont
	❑ Xylitol	❑ Lenzing (Austria)
	❑ Sorbitol	❑ ADM
Bioplastic intermediate - polymers	❑ Polyethylene terephthalate (PET)	❑ Toray, Virent, RTP Co.
	❑ Polyhydroxyalkanoates (PHAs)	❑ Metabolix, Meredian, Newlight, Telles
	❑ Polyamides (PA)	❑ Arizona Chem., Arkema, Rennovia
	❑ Starch blends	❑ Cereplast, Teknor Apex
	❑ Cellulose fibers	❑ Celanese Acetate, Eastman Chem., Innovia Films, Rotuba
	❑ Lignin and derivatives	❑ Weyerhaeuser

U.S. Renewable Chemicals Market Potential & Value added

(Nexant, 2014)

Groups	Key renewable chemical (s) – application	Corresponding technologies	Market potential (1000 metric tons)			Value added * (MM$/yr)	
			2012	2017	2022	2017	2022
C2	Ethylene / MEG – PET bottle; PE - packaging	❑ Corn ethanol dehydration ❑ Biomass to ethylene	0	0	1000	0	660
C3	Acrylic acid - diapers	❑ Dehydration of lactic acid	40	100	300	210	630
	Polyether Polyols – automotive seating						
C4	Lactic acid/ polylactic acid (PLA) - packaging 1,4 Butanediol (BDO) - solvents Butadiene – synthetic rubber	❑ Fermentation of sugars	100	150	400	200	530
Aromatics	Para-xylene – PET bottle & textile fibers	❑ Gevo: isobutanol to PX ❑ Virent: Aqueous phase reforming process ❑ Cool Planet: agricultural waste pyrolysis	<10	100	500	125	625
Specialty Oils	Vegetables oils – food, industrial applications	❑ Solazyme: Sugar-fed fermentation of genetically modified algae	20	400	1000	240	600
Total			165	750	3200	775	3045

* Value added: the difference between price of estimated renewable chemicals and the cost of raw materials.

Future Work

- To understand the drivers for renewable chemicals by U.S. biorefinery category;
- To identify potential renewable chemicals from U.S. biorefineries most likely to achieve economical viability; and
- To examine market strategies deployed by U.S. biorefineries; for example:
  - Porter's generic strategy
  - Ansoff's product-market growth strategy

Porter's Generic Strategy

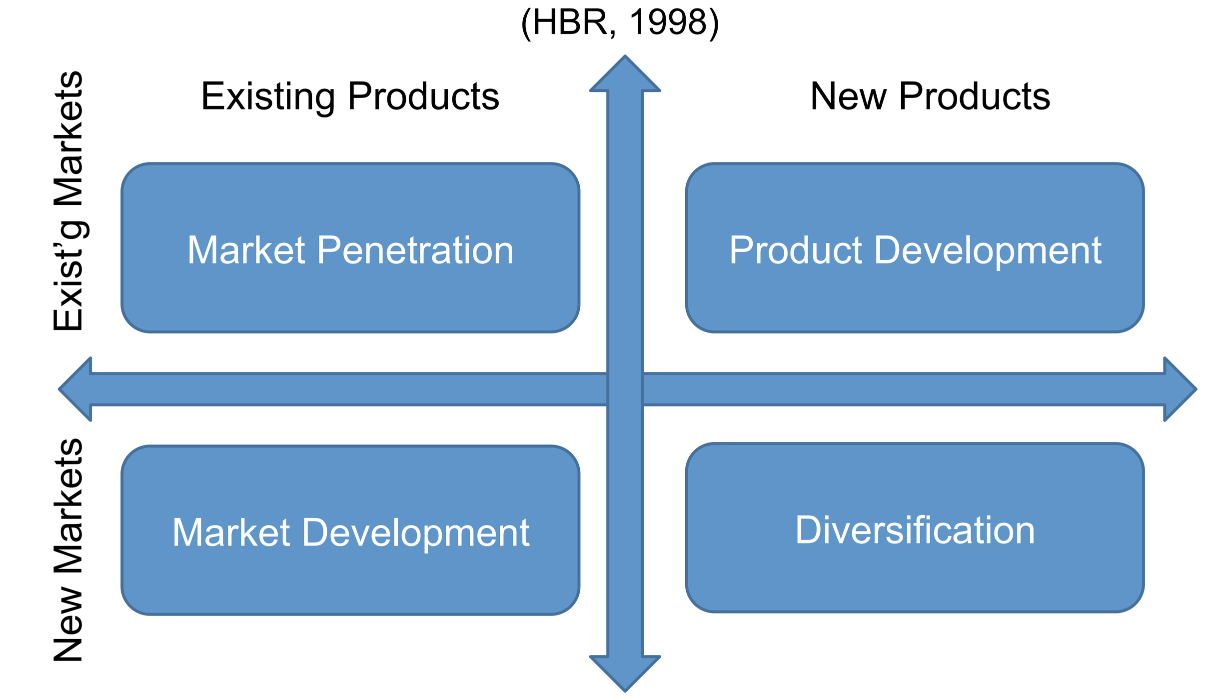
(Porter, 1985)

Target/Market Scope	Cost Advantage: Low Cost	Cost Advantage: Product/Service Uniqueness
Broad (Industry Wide)	Cost Leadership Strategy	Differentiation Strategy
Narrow (Market segment)	Focus Strategy (Low Cost)	Focus Strategy (Differentiation)

Strategy	Successful Firm's Internal Strength
Low-cost leadership	Access to capital investment, skill in efficient manufacturing, high level of engineering expertise, efficient distribution channels
Differentiation	Access to leading scientific research, creative product development team, strong sales team, corporate reputation for quality and innovation
Focus	High degree of customer loyalty, high product development strength to serve relatively narrow market segment

Ansoff's Product-Market Growth Strategy

(HBR, 1998)



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NARA
Northwest Advanced Renewables Alliance

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