

PERP Report

Unconventional Heavy Oils

04/05S9

November 2005



44 South Broadway, White Plains, New York 10601, USA

Tel: +1 914 609 0300 Fax: +1 914 609 0399

Copyright© by Nexant, Inc. 2005

“This report was prepared by Nexant, Inc (“Nexant”) and is part of the Process Evaluation/Research Planning (PERP). Except where specifically stated otherwise in this Report, the information contained herein is prepared on the basis of information that is publicly available, and contains no confidential third party technical information to the best knowledge of Nexant. Aforesaid information has not been independently verified or otherwise examined to determine its accuracy, completeness or financial feasibility.

Neither NEXANT, Subscriber nor any person acting on behalf of either assumes any liabilities with respect to the use of or for damages resulting from the use of any information contained in this Report. Nexant does not represent or warrant that any assumed conditions will come to pass.

The report is submitted on the understanding that the Subscriber will maintain the contents confidential except for the Subscriber’s internal use. The Report should not be reproduced, distributed or used without first obtaining prior written consent by Nexant. Each Subscriber agrees to use reasonable effort to protect the confidential nature of the Report.”

Contents

Section	Page
1 Summary	1
1.1 SETTING THE STAGE	1
1.1.1 Definition of Unconventional Heavy Oils	1
1.1.2 Occurrence of Unconventional Heavy Oils	1
1.1.3 Worldwide Oil Reserves	2
1.1.4 Worldwide Production	5
1.2 CANADA ALBERTA OIL SANDS - BITUMEN.....	5
1.2.1 Bitumen Resources	5
1.2.2 Bitumen Reserves	6
1.2.3 Bitumen Production	6
1.3 VENEZUELA ORINOCO BELT - EXTRA HEAVY OIL	7
1.3.1 Extra Heavy Oil Resources	7
1.3.2 Extra Heavy Oil Reserves	7
1.3.3 Extra Heavy Oil Production.....	8
1.4 TECHNOLOGY	8
1.4.1 Upstream Technology	8
1.4.2 Midstream Technology	10
1.4.3 Downstream Technology	10
1.5 PROJECT ECONOMICS	12
1.5.1 Development Cost.....	12
1.5.2 Supply Cost.....	13
1.5.3 Cost Comparison.....	13
1.6 FUTURE DEVELOPMENTS	14
1.6.1 Impact on Global Markets	14
1.6.2 Emerging Technological Trends.....	14
1.6.3 Key to Success	15
2 Introduction	16
2.1 DESCRIPTION OF UNCONVENTIONAL HEAVY OILS	17
2.2 NATURE OF EXTRA HEAVY OIL AND BITUMEN	19

2.3	WORLDWIDE OCCURRENCE OF RESOURCES	19
3	Setting the Scene	21
3.1	FORMATION OF UNCONVENTIONAL HEAVY OIL DEPOSITS	21
3.2	RESERVOIR TRAPS	22
3.3	RESOURCES AND RESERVES	22
3.3.1	Definitions and Interpretations	22
3.3.2	Worldwide Reserve Estimates	23
3.4	PRODUCTION	26
3.5	DRIVERS AND CHALLENGES FOR FUTURE DEVELOPMENT	27
3.6	OIL SHALE	29
4	Canada - Bitumen	30
4.1	ORIGIN OF BITUMEN RESOURCES	31
4.2	ALBERTA OIL SANDS	32
4.3	BITUMEN CHARACTERISTICS	33
4.4	RESOURCES AND RESERVES	34
4.4.1	Resources	34
4.4.2	Reserves	34
4.5	CHRONOLOGY OF MAJOR OIL SANDS DEVELOPMENTS	35
4.6	MINING PROJECTS	36
4.7	IN-SITU PROJECTS	37
4.8	BITUMEN PRODUCTION	39
4.9	BITUMEN UPGRADING	40
4.10	OIL MARKETS	41
4.10.1	Export Pipeline System	41
5	Venezuela - Extra Heavy Oil	44
5.1	ORIGIN OF THE EXTRA HEAVY OIL RESOURCES	45
5.2	ORINOCO BELT DEPOSIT	46
5.3	EXTRA HEAVY OIL CHARACTERISTICS	46
5.4	RESOURCES AND RESERVES	47
5.5	CHRONOLOGY OF MAJOR DEVELOPMENTS	48
5.6	IN-SITU PROJECTS	48

5.6.1	Project Descriptions	48
5.7	EXTRA HEAVY OIL PRODUCTION.....	50
5.8	UPGRADING OPERATIONS	51
5.9	MARKETS	52
5.9.1	Market Alternatives	52
5.9.2	Pipeline Transportation Systems.....	52
6	Technology	55
6.1	UPSTREAM TECHNOLOGY	56
6.1.1	Exploration and Resource Definition.....	56
6.1.2	Recovery of Unconventional Heavy Oils	57
6.1.3	Production of Unconventional Heavy Oil.....	65
6.2	MIDSTREAM TECHNOLOGY	71
6.2.1	Dilution with Lighter Oils and Products.....	71
6.2.2	Emulsions with Water and Surfactants	72
6.2.3	Other Transportation Solutions.....	72
6.3	DOWNSTREAM TECHNOLOGY.....	73
6.3.1	Processing Unconventional Heavy Oils.....	73
6.4	OTHER TECHNOLOGIES.....	79
6.4.1	Environmental Technology.....	79
6.4.2	Natural Gas and Electricity	81
7	Project Economics	84
7.1	DEVELOPMENT COST.....	84
7.1.1	Oil Sands Bitumen Projects	85
7.1.2	Orinoco Belt Extra Heavy Oil Projects.....	86
7.2	SUPPLY COST	87
7.2.1	Oil Sands Bitumen Project.....	87
7.2.2	Orinoco Belt Extra Heavy Oil Project	87
7.3	COMPARISON OF COSTS.....	88
8	Future Development	90
8.1	GLOBAL OIL PRODUCTION.....	90
8.2	CONSTRAINING FACTORS.....	91

8.3	IMPACT ON GLOBAL MARKETS	92
8.4	UNCONVENTIONAL HEAVY OIL PRODUCTION.....	93
8.5	MARKETS AND PRICING.....	94
8.6	EMERGING TECHNOLOGY	96
8.7	KEY TO SUCCESS.....	97
9	References.....	98
	Appendix	Page
A	PERP Program Title Index.....	A-1

Figure	Page
1.1 Technically Recoverable Oil Reserves	2
1.2 Percentage Distribution of Reserves by Region	3
1.3 Conventional and Non-Conventional Oil Reserves	4
1.4 Global Oil Production Forecast	15
2.1 Comparison between Discovery and Consumption	16
4.1 Alberta Oil Sands	30
4.2 Oil and Bitumen Migration Pattern.....	31
4.3 Oil Sands Composition	32
4.4 Open Pit Bitumen Mining.....	37
4.5 Oil Sands Production History	39
4.6 Oils Sands Upgrading Plant	40
4.7 Oil Sands Pipeline System	42
4.8 U.S. and Canada Trunk Lines	43
5.1 Venezuela Sedimentary Basins.....	44
5.2 Structural Cross Section.....	45
5.3 Orinoco Belt Projects.....	49
5.4 Production History – Extra Heavy Oil.....	50
5.5 Production History – Syncrude Oil.....	50
5.6 Upgrading Plant	51
5.7 Orinoco Belt Market Alternatives.....	53
5.8 Export Pipeline Systems	54
6.1 Crude Oil Viscosity vs. Temperature.....	60
6.2 Technology Maturity – Enhanced Recovery	61
6.3 Cyclic Steam Stimulation	62
6.4 Steamed Assisted Gravity Drainage (SAGD).....	63
6.5 Thai™ Process	64
6.6 Mining and Extraction of Bitumen	66
6.7 Multilateral Horizontal Well.....	68
6.8 Primary Upgrading Technology	74

6.9	Section Figure Caption	75
6.10	Secondary Upgrading.....	77
6.11	Syncrude Light Fractions vs. Degree of Upgrading	78
7.1	Syncrude Oil Breakdown Prices	88
7.2	Operating Costs.....	89
8.1	Global Oil Production Forecast	90
8.2	Alberta Oil Sands – Production Forecast.....	93
8.3	Unconventional Heavy Oils – Production Forecast.....	94

Table	Page	
1.1	Conventional and Un-Conventional Oil Production.....	5
1.2	Canadian Bitumen Resource and Reserves.....	6
1.3	Extra Heavy Oil Reserves	7
3.1	Technically Recoverable Oil Reserves	23
3.2	Technically Recoverable Heavy Oil, Extra Heavy Oil and Bitumen	24
3.3	Conventional and Non-Conventional Oil Reserves.....	25
3.4	Conventional and Non-Conventional Oil Production.....	26
3.5	Characteristics Impacting the Recoverability of Unconventional Heavy Oils	28
4.1	Comparison of Oil Properties	33
4.2	Reserves Development.....	34
4.3	Oil Sands Mining Projects	36
4.4	Oil Sands In-Situ Projects	37-38
4.5	Principal Gathering Pipelines	41
5.1	Comparison of Typical Unconventional Oil Properties.....	46
5.2	Extra Heavy Oil Reserves	47
5.3	Orinoco Belt Projects.....	49
5.4	Description of Pipeline Systems	54
6.1	Comparison of Pipeline Transportation Technologies	73
7.1	Operating and Upgrading Costs.....	85