CCSテクニカルワークショップ2021
－CCSの社会実装に向けたCO2地中貯留技術の実用化－
2021年1月27日

CCS for Business
CCSの社会実装
- Partnership by Public, Business, and Finance -
～産業、政府、金融の協力～

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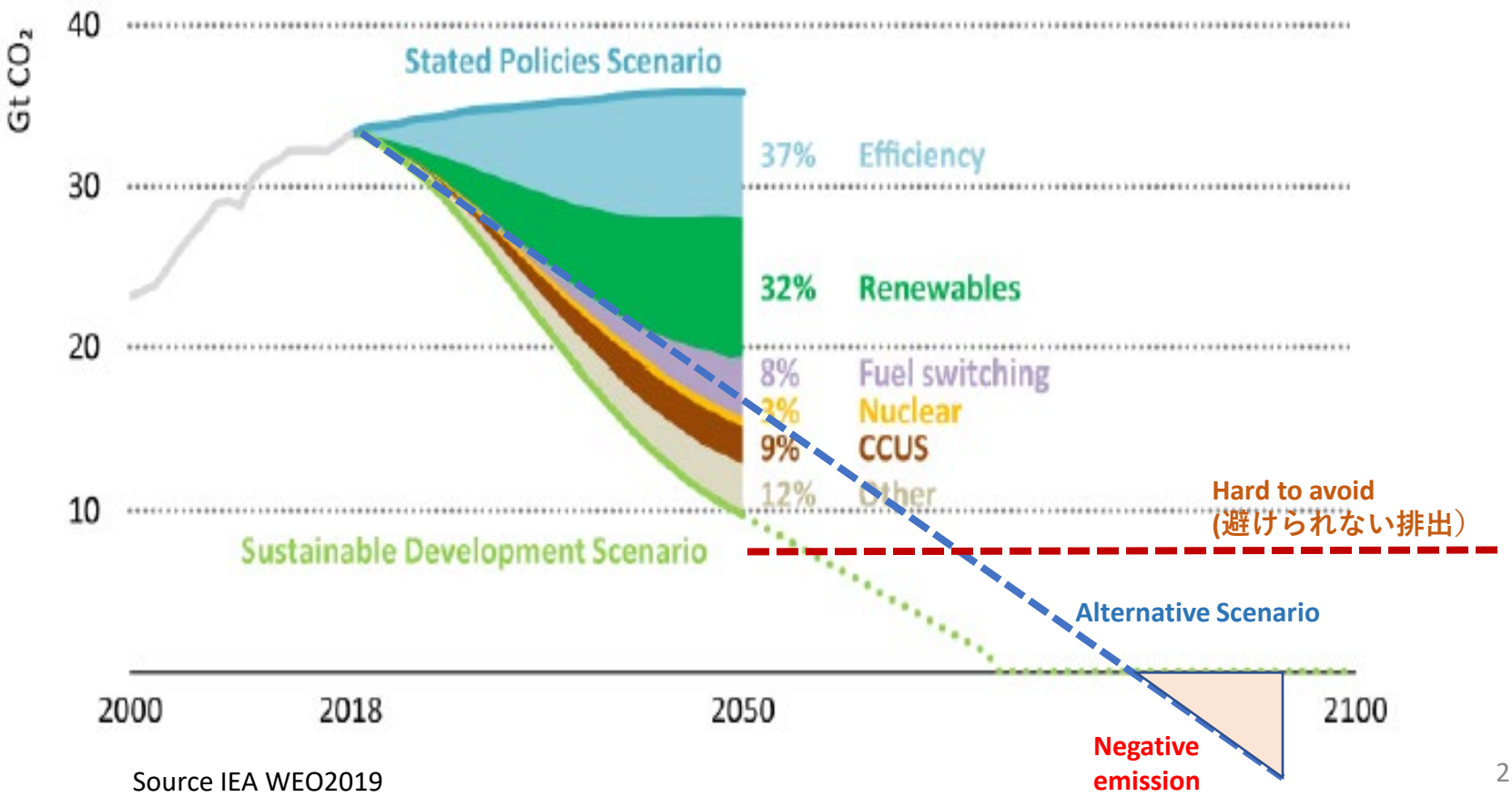
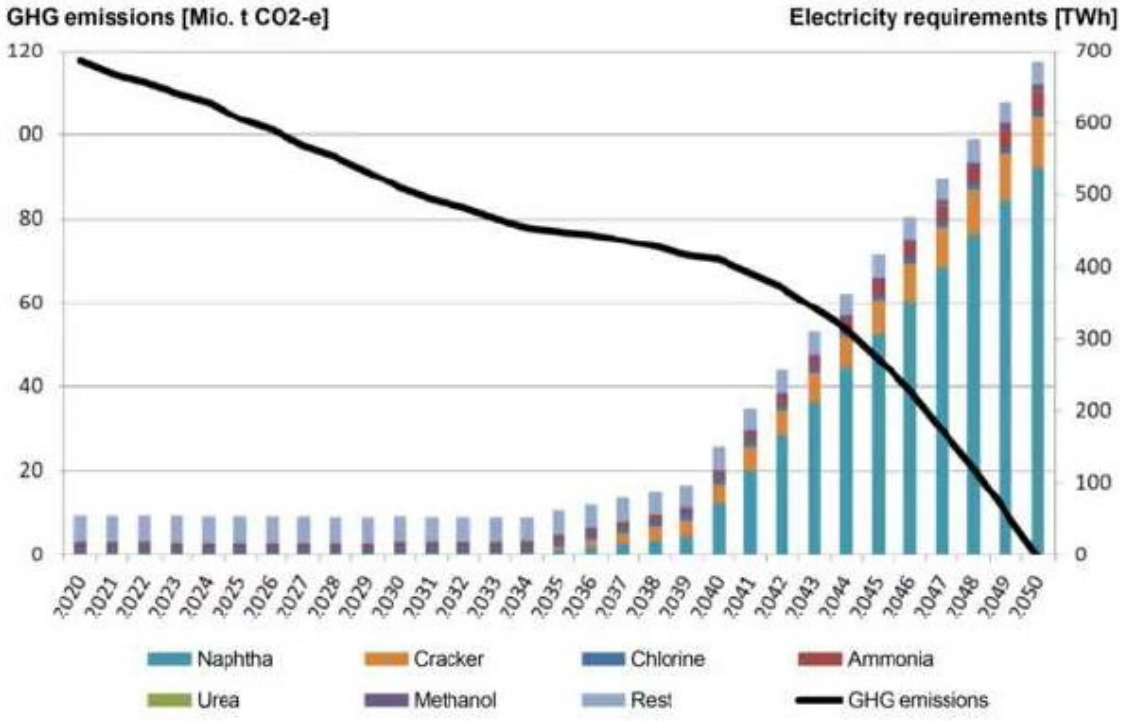
2℃ target and Negative emission

- More than 120 countries commit Net Zero Emission. Overshooting scenario is considered as an alternative scenario for achieving 2 degree target due to the “Hard to avoid emission” and uncertainty of technology innovation. / 120か国以上がネットゼロ排出を宣言。 他方でHard to Avoid排出（避けがたい排出）からオーバーシューテイングシナリオも俎上に。
- Negative emission:：Biomass CCS, Direct Air Capture



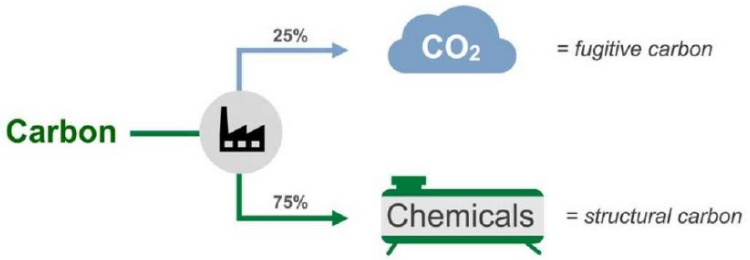
Source IEA WEO2019

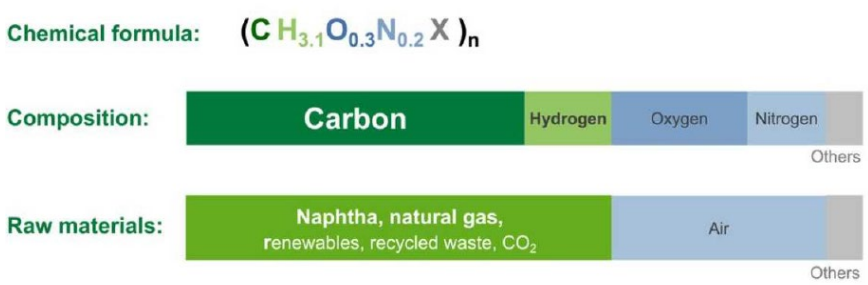
Chemical Industry - a case of Hard to Avoid emission industry
化学産業 – Hard to Avoid排出の例



Net Zero emission for Chemical Industry

- ✓ Net zero emission is technically possible, but huge amount of electricity is needed for net zero emission / ネットゼロは可能だが膨大な電力が必要
- ✓ For net zero emission, Germany chemical needs seven times more electricity than Germany's current total demand / ドイツ化学産業でゼロエミを行えばドイツ全電力需要の7倍の電力が必要



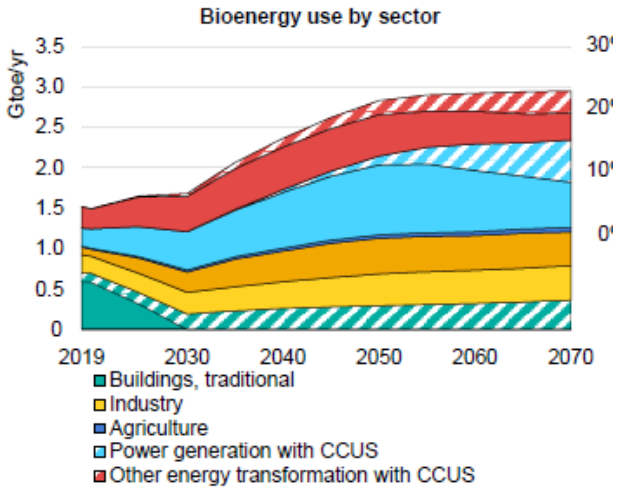


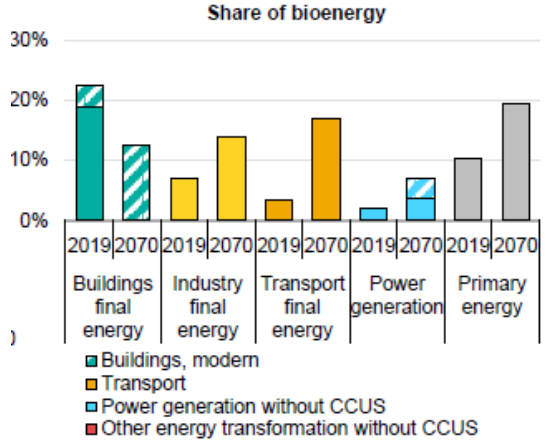
Source The VCI industry association

Role and limitation of Bioenergy/バイオエネルギーの量的制約

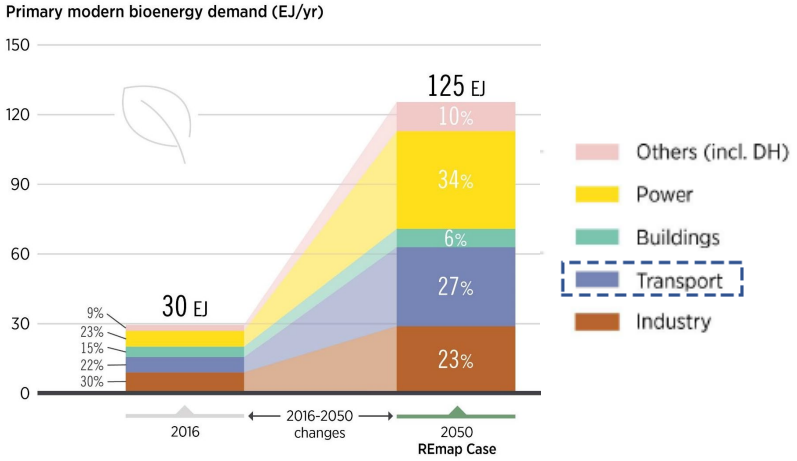
- Bioenergy plays important role in achieving the 2 degree target / バイオエネルギーは2度目標で重要な役割
- Barriers / 課題;
- Bioenergy is competitive with oil base when carbon price is $150/tCO2.（IEA ETP2020) / 価格制約
- Limitation of supply because: Need to double the current biomass supply./ 量的制約

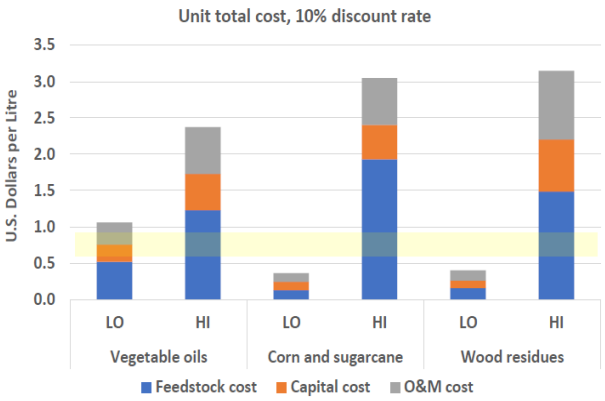
IEA





IRENA





Kerosene Price at Crude Oil Price of $50-100 per barrel

CCS is indispensable option/欠かせないオプション

- CCS is certainly an essential option for achieving the net zero goal and market with big potential. However, only a few companies have made serious investments in CCS, and no large influx of investment funds has been observed.
- CCSは不可欠な選択肢であり、大きな潜在市場。しかし投資は限定的であり、投資資金流入もない。

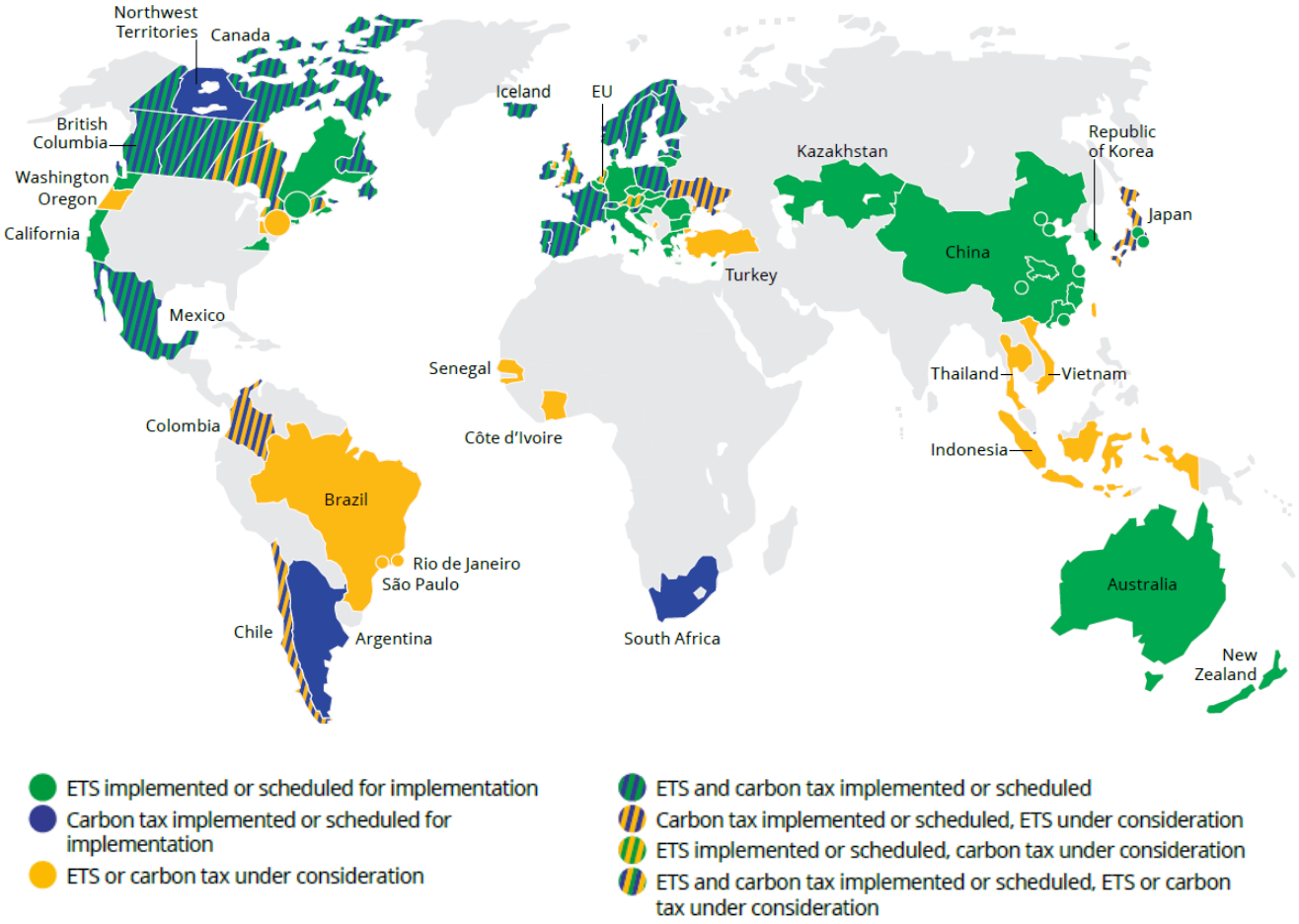
Barriers for CCS investment

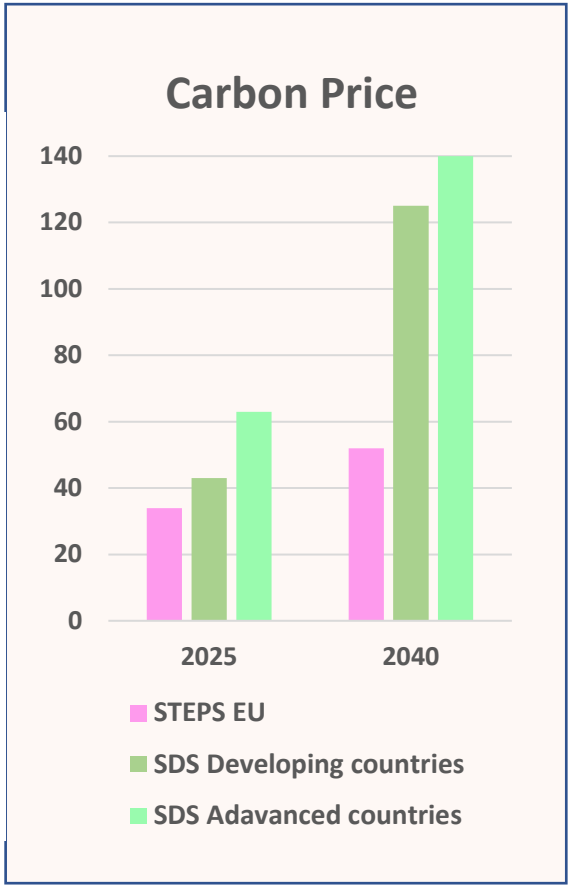
Issues	facts	Counter measures
Economics	✓ **Limited or zero income from CO2 containment / 貯留自体では収入を生まない**	✓ **Carbon pricing(regulation) /規制** ✓ **Emission trading(incentives)/インセンテイブ** ✓ **Infrastructure by public(cost reduction)/インフラ整備**
Legal framework	✓ **liability for long-term safety containment / 長期の安定貯留の責任**	✓ **Regulatory development using ISO and international best practice/ISOやベストプラクテイスを活用した法整備** ✓ **Mechanism to undertake long-term monitoring of storage by government/政府による長期安定貯留責任に引き受け**
Technology	✓ **Uncertainty of long term containment / 長期貯留** ✓ **Innovation for cost down / コスト削減のイノベーション**	✓ **Continuation of the demonstration project / 長期の実証事業** ✓ **R&D investment in capture technologies. Diversified investment in various technologies/ 回収技術のR&D。多様な技術への分散投資**
Reputation risk and skepticism	✓ **The most difficult. both science and subjectivity / 最も困難。科学と主観の両面で課題**	✓ **Safe guards system and accumulation of projects / 安全基準整備と実績の積み重ね** ✓ **Public relations and communications / 広報**

Economics

Carbon Pricing in the world

- Carbon Pricing (Emission trading and carbon tax) is adopted in many countries. It is expected to be increased and its rage depends on the carbon policy.
- カーボンプライスは多くの国で導入。カーボンプライスは上昇するが、政策次第。





Source World Bank, State and Trend of Carbon Market 2020

Net Zero Emission by corporate and role of offset

- Many companies, including energy industry, declare Net Zero Emissions. CCS contributes to the reduction of LCA emissions or the creation of offset credits.
- 多く企業がネットゼロを宣言。CCSはLCA排出削減、クレジット創出に貢献

Hierarchy Approach

Target setting / 目標設定

Reduction of energy consumption / 消費削減

- ✓ **Improvement of energy efficiency/ 効率改善**
- ✓ **Reduction of energy demand (e.g. circular economy) / 需要削減**

Decarbonizing of fuel/energy / エネルギーの脱炭素化

- ✓ **Fuel switch**
- ✓ **Renewable, zero emission fuel**
- ✓ **Nuclear**
- ✓ **Fossil fuel + CCS**

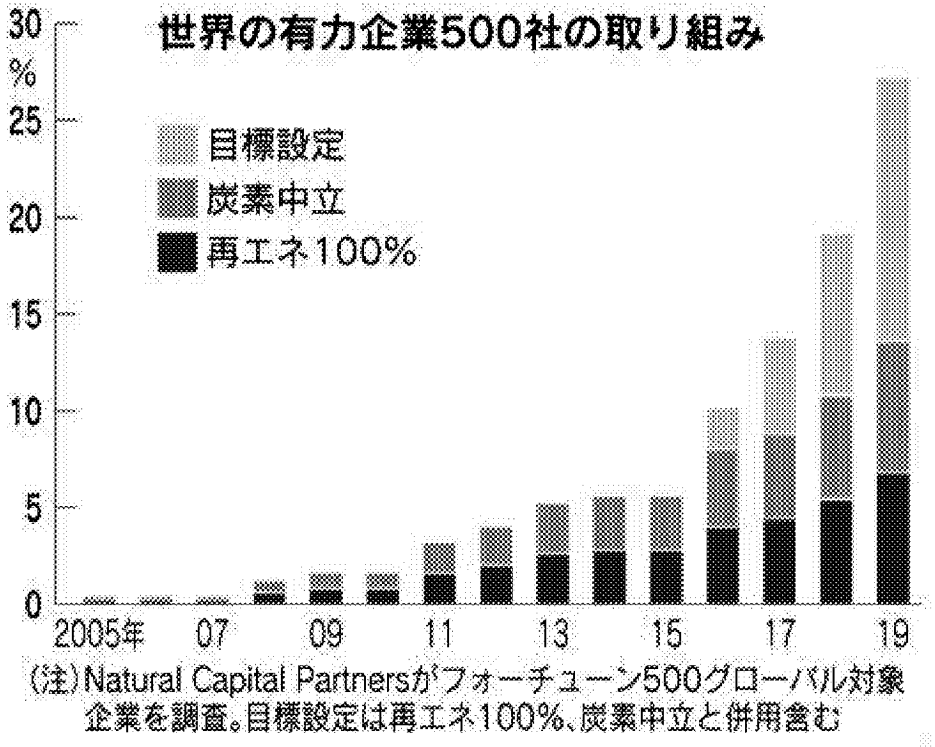
Offset / オフセット

Specification for the demonstration of carbon neutrality
（炭素中立の宣言）

Source BSI(British Standards Institution）

Net Zero Declaration/企業のネットゼロへの取り組み

- Voluntary action by industry is increasing after Paris Agreement/パリ協定以降企業の自主的な取り組みは急増
- Energy and energy intensive industry declares Net Zero too/エネルギー産業・エネルギー多消費産業もネットゼロを宣言



日経産業新聞「Earth新潮流」から

温暖化ガスの実質ゼロ宣言が広がっている	
業種	主な企業
エネルギー	ロイヤル・ダッチ・シェル、ＢＰ、トタル、エーオン、ＪＥＲＡ
資源（非鉄など）	リオ・ティント、ＢＨＰグループ、アングロ・アメリカン、グレンコア
素材	アルセロール・ミタル、ダウ・ケミカル
食品・流通	ネスレ、ダノン、マークス＆スペンサー、テスコ
運輸	マースク（海運）、ブリティッシュ・エアウェイズ、カンタス航空、日本航空、ＤＨＬ
ＩＴ・通信	マイクロソフト、アマゾン、ＢＴ

(注) 2050年やそれ以前の実質ゼロや炭素中立を宣言した企業

日経産業新聞「Earth新潮流」から

Offset credits – as a potential of revenue source for CCS

- Offset credits can be an important source of income. Conditions; methodology and demand.
- オフセットクレジットは収入源になりうる。ただし、方法論と需要がカギ。

- Demand: compliance(regulation purpose) and voluntary offsets
- 需要は規制目的かボランタリーオフセットか。

Voluntary offsets
（ICROA Recommendation)

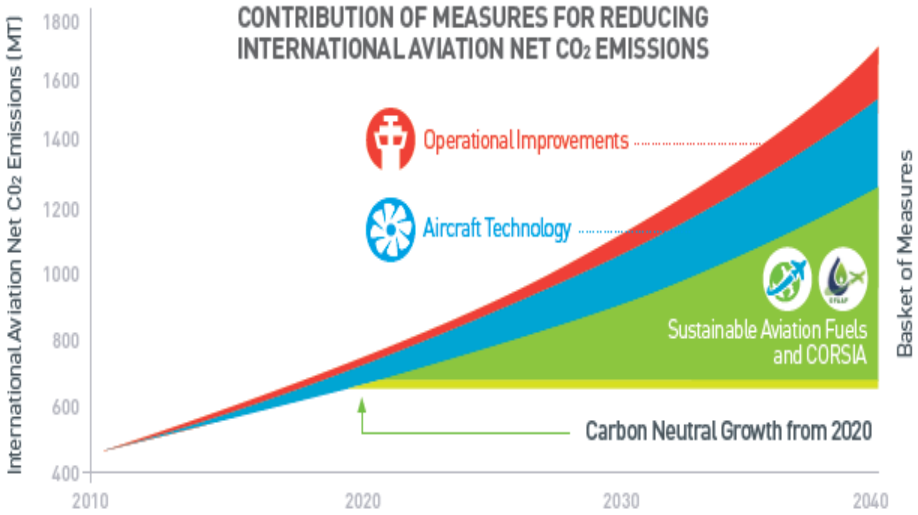
- Clean Development Mechanism
- Climate Action Reserve
- Gold Standard
- Joint Implementation
- Verra‟s Verified Carbon
- Standard
- American Carbon Registry
- Emissions Reduction Fund (ERF) of the Australian Government

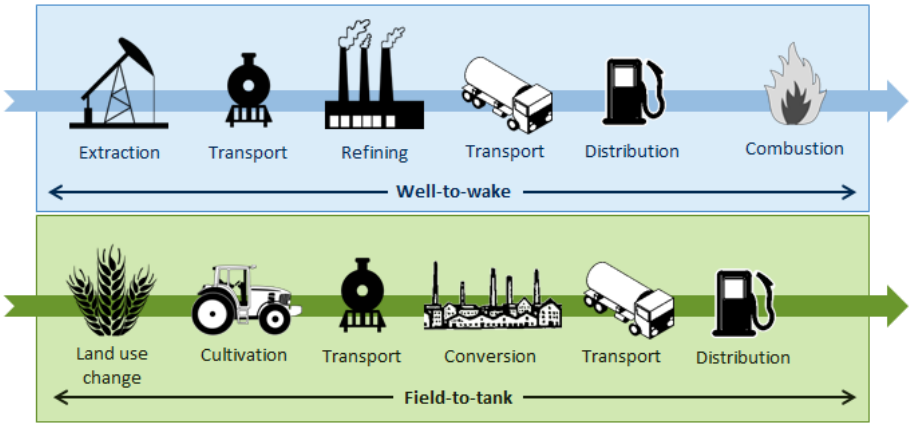
ICAO CORSIA
（国際航空の制度）

- American Carbon Registry
- Architecture for REDD+ Transactions
- China GHG Voluntary Emission Reduction Program
- Clean Development Mechanism (CDM)
- Climate Action Reserve (CAR)
- The Gold Standard (GS)
- Verified Carbon Standard (VCS)

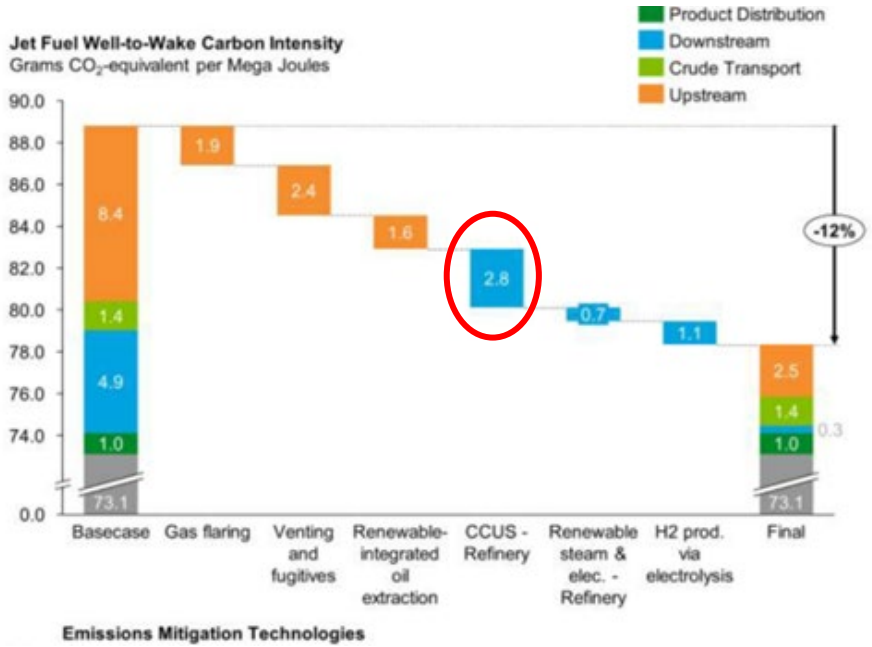
Lower carbon fuel – as an option of revenue

- **Basket measures for Carbon Neutral (CORSIA); offset and low carbon fuel are allowed. Petro base low carbon fuel (LCAF) is an option, in addition to bio fuel / 2020年以降の排出増加なし（炭素中立成長）。オフセットや低炭素燃料は選択肢(CORSIA)**
- **Emission decline by Covid-19 / Covid-19による排出量の減少**





- ✓ Saudi's proposal for LCAF. CCS is included / CCSを含むサウジのLCAF提案



Source Workshop by Mitsui at COP25

Feasibility of Carbon Neutral Jet Fuel

- **LCAF for CORSIA is under consideration; calculation of reduction, sustainable criteria etc. /LCAFによる排出削減量の計算、持続可能性要件などを検討中.**

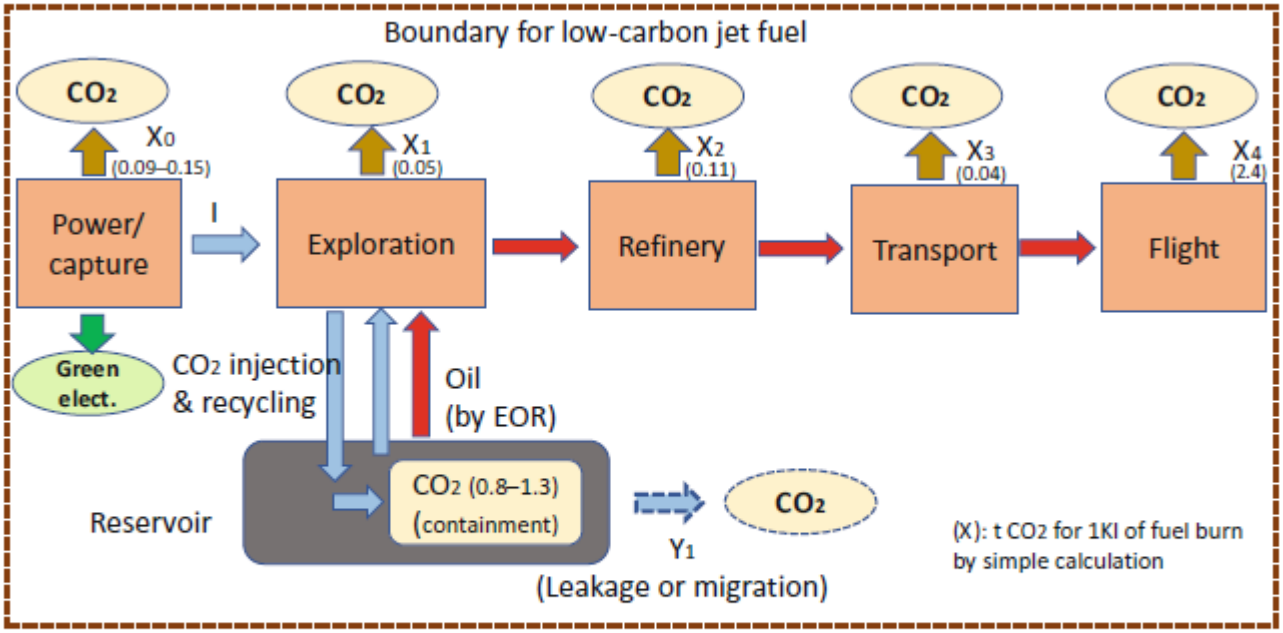


Figure 6: Supply Chain of Low-Carbon Jet Fuel. Net CO_2 Emission Reduction = I – (Σ X0-3 +Y1) *Y1 = Zero. Low-Carbon Jet Fuel may Reduce Life Cycle Emission by 20%–40% from Conventional Jet Fuel, Depending on the Amount of Stored CO_2. (Sources: Hongo 2017, 2018a)

Source Takashi Hongo, Carbon Pricing to Promote Green Energy Projects, Springer

- ✓ **CO2 reduction – double counting (allocation for capture at power sector and aviation) / CO2 削減量の計算 – 二重計上防止（発電事業と航空の分配）**
- ✓ **Tracking of LCAF at supply chain / サプライチェーンの中での追跡**
- ✓ **Increase of oil production / 原油増産効果**

Economics – Sensitivity analysis of EOR

- **CO2 EOR has crude oil revenue. Storage is an additional source of revenue when carbon price is adopted / CO2 EORには原油収入あり。Carbon Priceがあれば貯留が追加収入源。**
- **A key for economic is transportation infra / 輸送インフラは経済性のカギ**

Table 8: Sensitivity of Economics of EOR in US

	Base Case	Case 1	Case 2	Case 3
<Assumption>				
Oil price ($/bl)	100	50	60	60
CO_2 cost ($/t CO_2)	50	50	80	80
Carbon price ($/t CO_2)				15
< Operation (for 1bl)>				
(Revenue)				
Oil sales	100.0	60.0	60.0	60.0
(Cost)				
Royalties & tax	21.6	10.8	13.0	13.0
CO_2 purchase	17.5	17.5	28.0	28.0
CO_2 recycle operation	12.0	12.0	12.0	12.0
Other OPEX & CAPEX	12.0	12.0	12.0	12.0
(total cost)	63.1	52.3	65.0	65.0
Carbon credit revenue	–	–	–	5.3
Balance	36.9	−2.3	−5.0	0.3

Notes: 1. The base model is prepared by Michael L. Godec (Advanced Resources International), "Opportunities for Utilizing Anthropogenic CO_2 for Enhanced Oil Recovery and CO_2 Storage" and modified by author.
2. 0.35 t CO_2 is consumed/stored for 1 barrel of oil production according to this model (as an assumption).
3. CO_2 cost is the cost for CO_2 supplied to an EOR operator. Cost of captured CO_2 at this model includes capture and transportation costs.
Source: Author.

US EOR
(pipeline infra is available)

Break even cost
- ✓ **Oil price: $60/bl**
- ✓ **Capture cost: $80/tCO2**
- ✓ **Carbon price: $15/tCO2**

Break even cost
- ✓ **油価格: $60/bl**
- ✓ **回収コスト: $80/tCO2**
- ✓ **炭素価格Carbon price: $15/tCO2**

Source Takashi Hongo, Carbon Pricing to Promote Green Energy Projects, Springer

Risk Analysis for Investment/Finance

- **Risk control table for investment and finance; political risk, commercial risk and technology risk / リスクコントロール表；政治リスク、商業リスク、技術リスク**

Table 4: Risk Control Table for Finance

	Capture	EOR (injection and containment)
(Political risk)		
Foreign currency exchange	Low (~medium), depending on project country, but in general oil-producing country's risk is low (mostly US$ linked)	Low (oil price is US$ linked)
Regulation/ incentive	Low (~medium), depending on project country, but in general oil-producing country's risk is low	Low (~medium), depending on project country, but in general oil-producing country's risk is low
Contact breach (incentive)	Low (~medium), depending on project country, but in general oil-producing country's risk is low	Low (~medium), depending on project country, but in general oil-producing country's risk is low
Political turbulence	Depending on project country	Depending on project country
(Commercial risk)		
Market – oil	Medium (CO_2 purchase by oil producer)	Medium–high
Market – carbon premium	Medium, low (long term)	Medium, low (long term)
Energy and material supply	Low (heat and power supply for the process)	Low
Sponsor	Medium (electricity power company)	Low (oil company)
Funding (working capital)	Low–medium	Low

- ✓ **In general, CO2 EOR is lower risk than geological CCS / 全体としてCO2 EORが帯水層CCSに比べてリスクは低い**
- ✓ **Oil price risk; volatility and long term demand / 油価変動と長期的な需要**
- ✓ **Technology risk; long term safe containment / 技術リスクでは長期の安全な貯留がリスク**

Risk Analysis for Investment/Finance – cont'd

(Technology risk)		
Construction	High (need more experience and innovation)	Low (based on experience)
Performance	High (need more experience and innovation)	Low (based on experience)
Overall cost	High (need more experience and innovation)	Low (based on experience)
Reliability	High (need more experience and innovation)	Low (based on experience)
Safe containment	—	Low (based on experience)

Depending on regulation/現地規制次第

Source Takashi Hongo, Carbon Pricing to Promote Green Energy Projects, Springer

Legal framework

National regulation – ISO for CCS

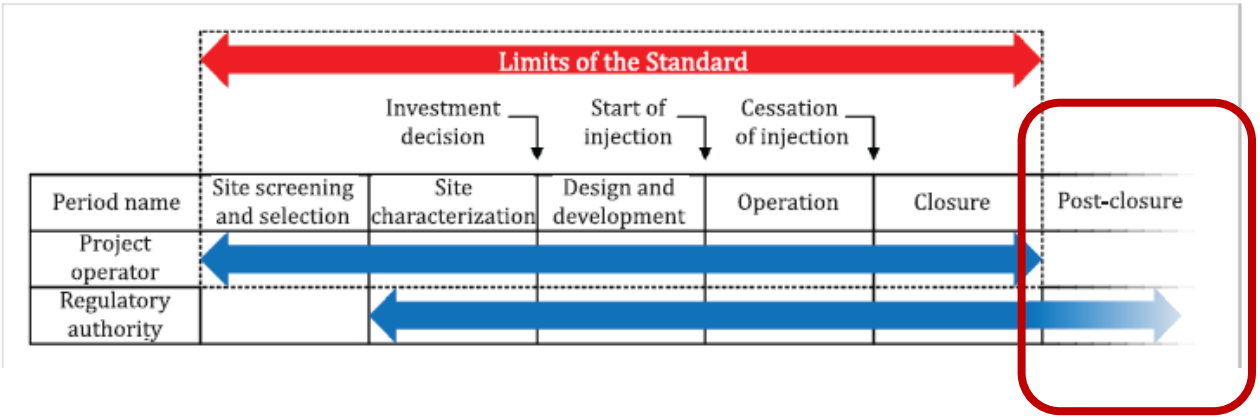
- **Serious risk is liability for post closure period / 最大のリスクはPost Closure**
- **Regulation as safety net is needed / 止まり木としての規制整備を期待**

ISO 27914 (Geological CCS)

4 Management systems
5 Site screening, selection, and characterization
6 Risk management
7 Well infrastructure
8 CO2 storage site injection operation
9 Monitoring and verification
10 Site closure
10.2 Criteria for site closure
10.3 Closure plan
10.4 Closure qualification process

ISO 27916 (CO2 EOR)

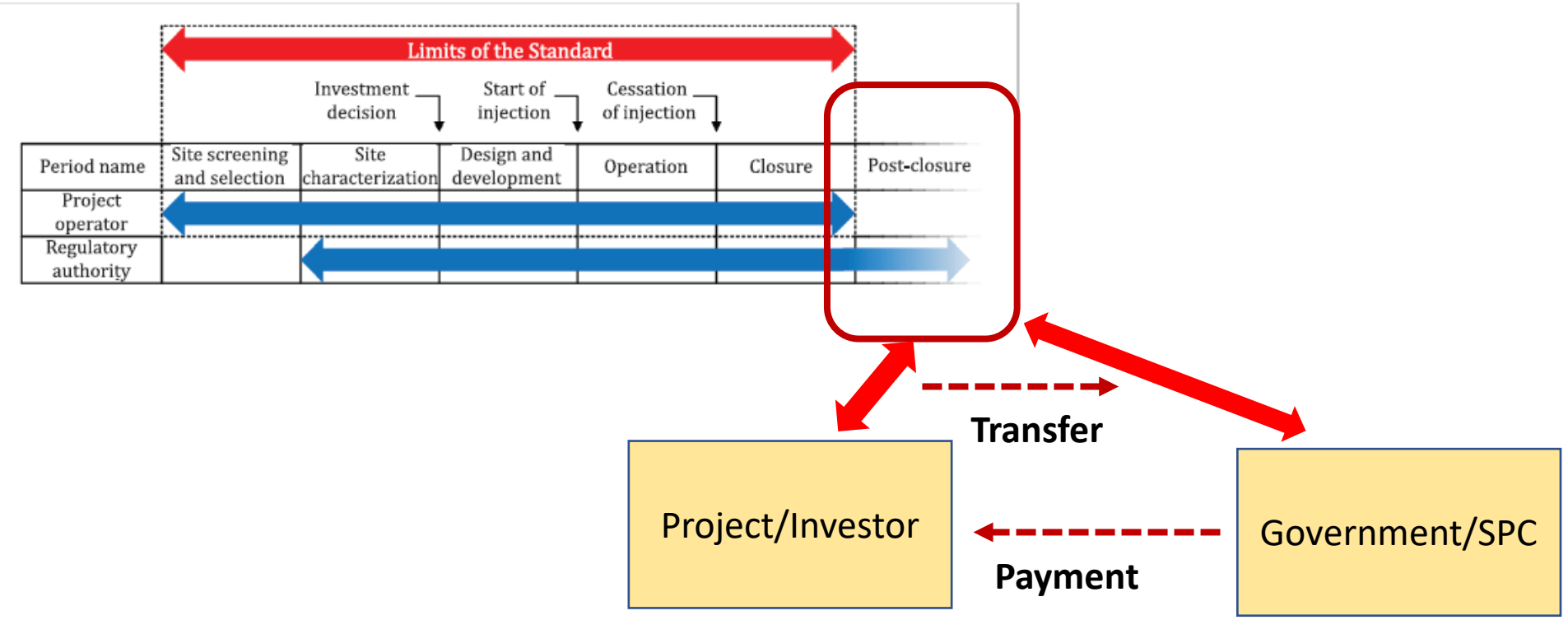
4 Documentation
5 EOR complex description, qualification and construction
6 Containment assurance and monitoring within the EOR complex
7 Well construction
8 Quantification
9 Record keeping and missing data
10 Project termination
10.2 Periodic assurance of containment
10.3 Termination plan
10.4 Requisites for termination
10.5 CO2-EOR project termination
10.6 Post termination



Assurance of safe, long-term containment shall consider fluid movement to ensure that leakage out of the EOR complex is unlikely. Some jurisdictions might require post-termination monitoring or follow up activities.

Long term liability – transfer mechanism
（長期のリスクの移転メカニズム）

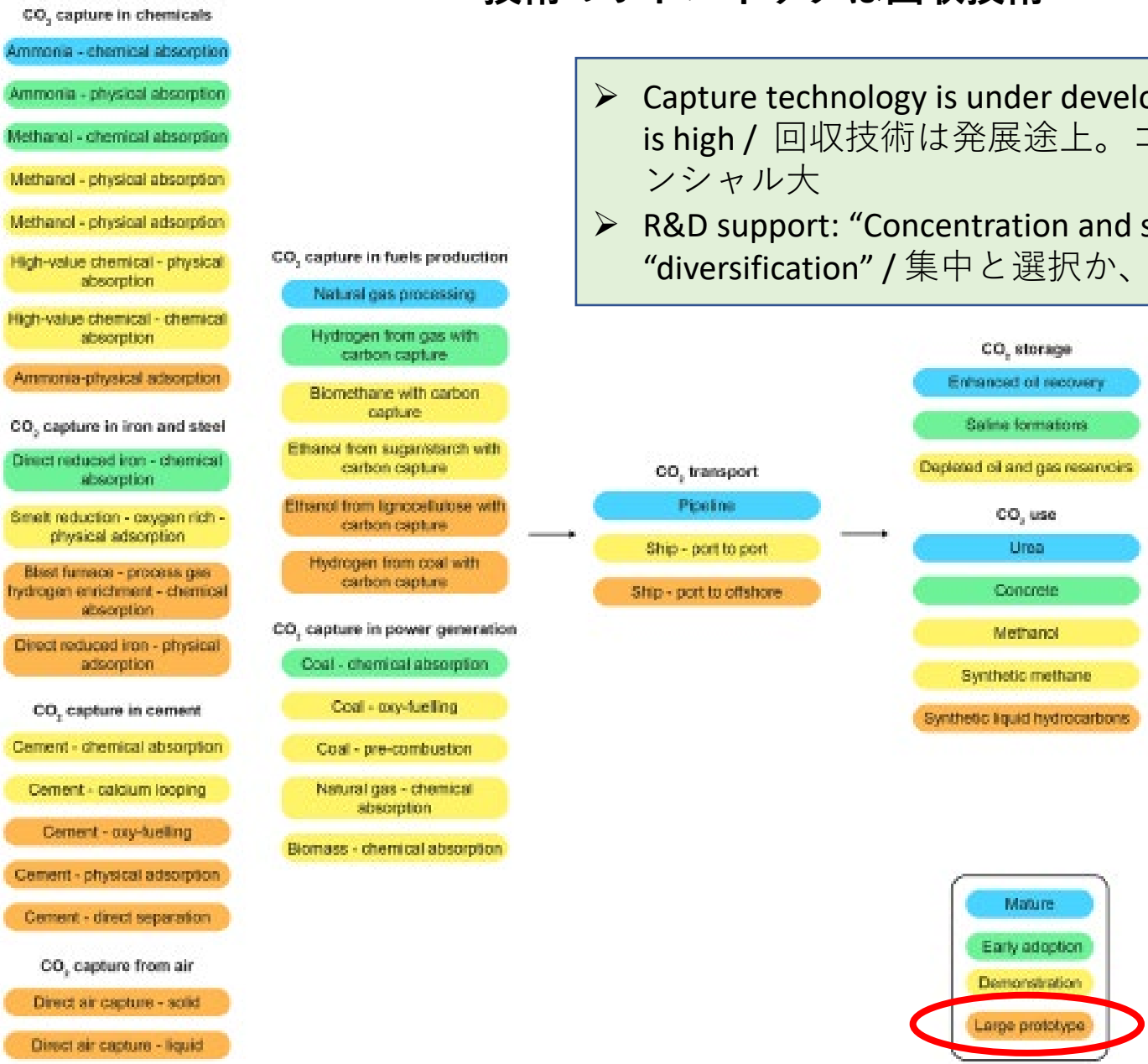
- **Hard to hold business risk for a long period of time (20, 50 years or more)/ 長期間（20,50年～）事業リスクを保有することは困難**



Fix earnings by transferring long-term liability / 長期のモニタリングリスクを移転ですることで収益を確定させる

Technology

Technology Innovation – bottleneck of CCS Technology
技術のボトルネックは回収技術



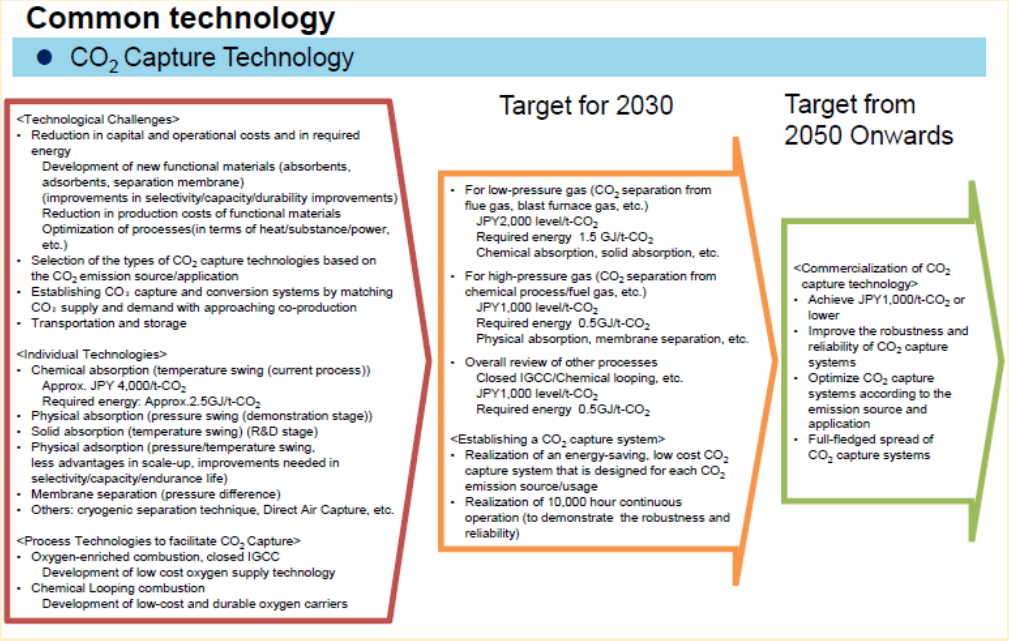
- Capture technology is under developed. Reduction room is high / 回収技術は発展途上。コスト引き下げポテンシャル大
- R&D support: “Concentration and selection” VS “diversification” / 集中と選択か、分散投資か？

under developed
（未成熟）

Technology Road Map of Innovation – long way to go
技術のイノベーションは長い道のり

- Innovation in lowering capture costs has a long way to go / 回収コスト引き下げのイノベーションは長い道のり

Road Map in Japan
2020 Yen 4000/tCO2
2030 Yen 1000-2000/tCO2
2050 Yen 1000/tCO2



- 20-30 years is needed to realize innovation and diffusion / イノベーションと普及には20-30年は必要

- Japanese budget is limited to up tp 5 years, which does not cover the time needed for innovation. R&D scientist have to find next job after 5 years program period. / 予算は5年までででinnovationに必要な期間をカバーできず。研究者も5年で次の職探し。

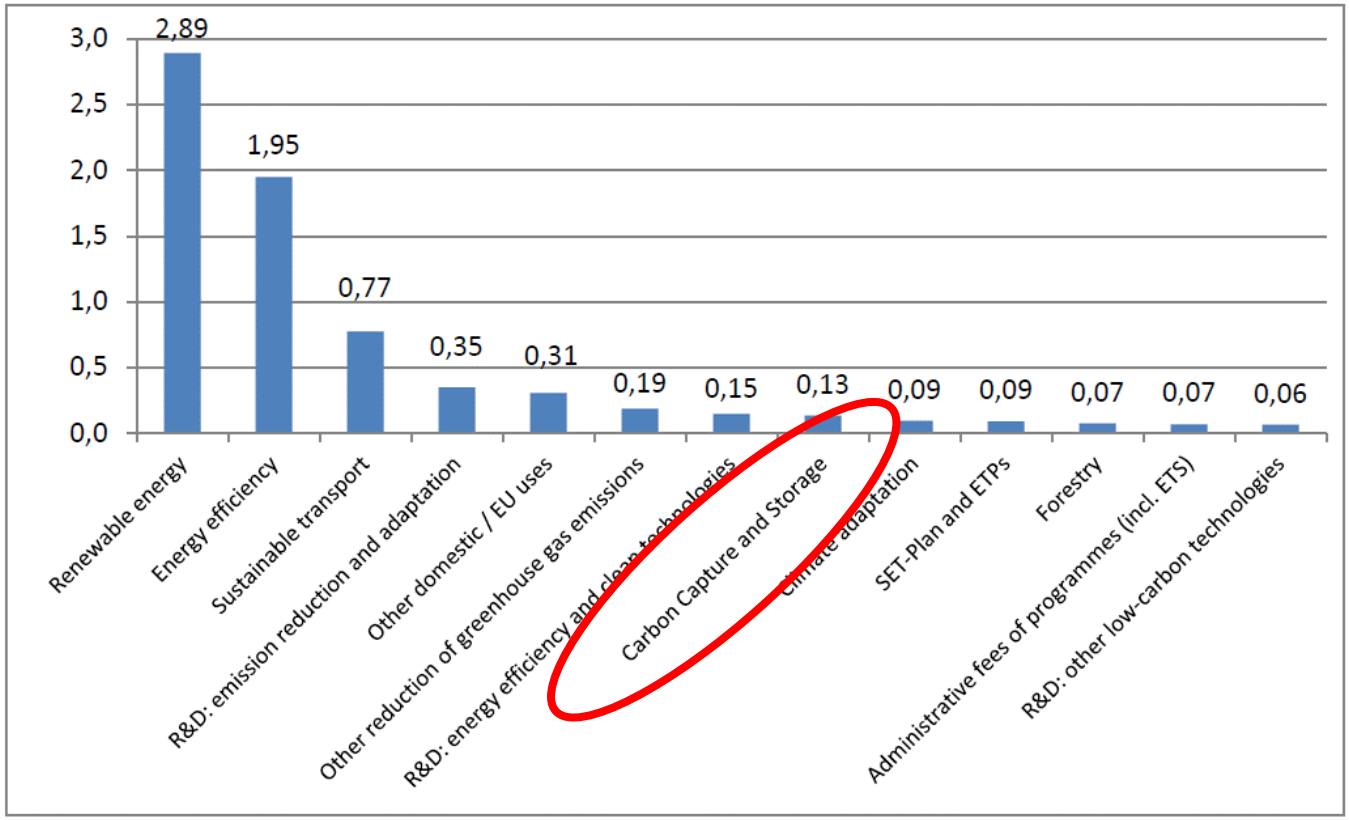
- Science and technology budget system needs to be reconstructed 科学技術予算制度の見直しが

Revenue from carbon pricing / カーボンプライスによる収入

- Innovation in lowering capture costs has a long way to go. Securing stable financial resources is an important. / 回収コスト引き下げのイノベーションは長い道のり。財源確保は重要な課題。

Use of Auction revenue by EU ETA

Billion EURO



Source EU Auction Revenue Report 2017

- Carbon pricing is considering in Japan / 日本でもCarbon Pricingの導入検討

Prime Minister Suga instructed considering the adoption of Carbon Pricing contributing for growth strategy （Minister of Economy, Trade and industry and Minister of Environment on 21 December 20290) /菅総理から成長戦略に資するCarbon Pricingの検討の指示（2020年12月21日、経済産業大臣、環境大臣）

Japan Model for CCS

Japanese Model / 日本型モデル

- Developed in Japan, deployed overseas / 日本で開発、海外に展開
- Green Hydrogen VS Blue Hydrogen or Green Hydrogen and Green Hydrogen / ゼロエミ燃料 Green 対 Blue
- Infrastructure development by PPP and competition for R&D support for capture technologies / PPP によるインフラ整備と回収技術の競争的R&D