

Recovering Cryogenic Refrigeration Energy From LNG Terminals for Data Center Cooling and Power



**Technology
Presentation**

**Datacentres
Europe 2014**

May 2014



Cooling and Power Opportunity – LNG Terminals

- **Liquefied Natural Gas (LNG) terminals**
 - LNG – mostly methane – a cryogenic liquid at -162°C (-260°F)
 - Expands 600x during liquid to gas phase change
 - Massive energy stored during liquefaction is lost
 - Mission-critical, continuous operation for natural gas send-out
 - **~15-700 MW/hr refrigeration capacity typically unused**
 - Some terminals burn ~1.75% of supply to heat LNG to 60°F for send-out
 - 20-40 year contracts for LNG delivery and gas pipeline send-out
- **LNG industry growth**
 - Production doubling 2005-2015
 - 4.5% annual growth projected 2015-2025
 - New shale gas supplies create expanding market for LNG
 - Political uncertainty driving growth in Europe (e.g. Ukraine)

TeraCool Technology

Heat Exchange

- Recover “waste cold” from LNG terminals to cool data centers
- Waste heat from data centers lowers LNG vaporization costs and emissions

Expansion Turbines

- Generate emissions free, base-load power for data centers via non-combustion expansion turbines
- **Flexible and standard design approaches**
- **Best fit where power costs and/or ambient temps are high and sustainability goals are present**

***TeraCool - at nexus of two critical and rapidly growing sectors:
LNG Terminals and Data Centers***

LNG Cold Recovery Examples

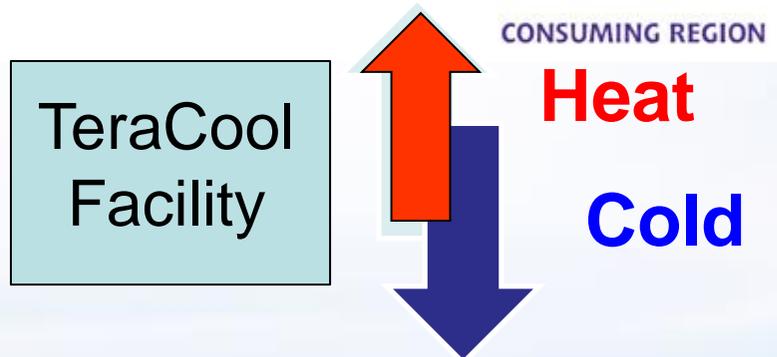
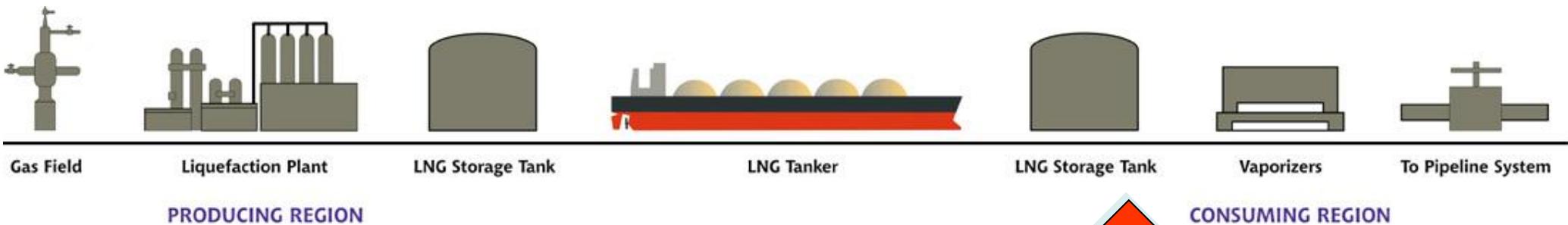
Selected technologies used in LNG cold recovery:

- Air and condensate cooling for CHP and CCGT
- Air separation and liquefaction (industrial gas production)
- Chemical manufacturing
- Clean power generation via expansion turbines
- Frozen food, cold warehouse, dry ice, aquaculture

Selected countries using LNG cold recovery:

- Belgium
- China
- France
- India
- Japan
- Netherlands
- South Korea
- Spain
- Taiwan
- UK

LNG Life Cycle



Interconnection between storage tank and vaporizer, supplementing existing LNG vaporizers

Data Center



Terminal Safety Measures

In ~70+ years of modern commercial LNG use, no major accidents, safety or security problems have occurred in port or at sea

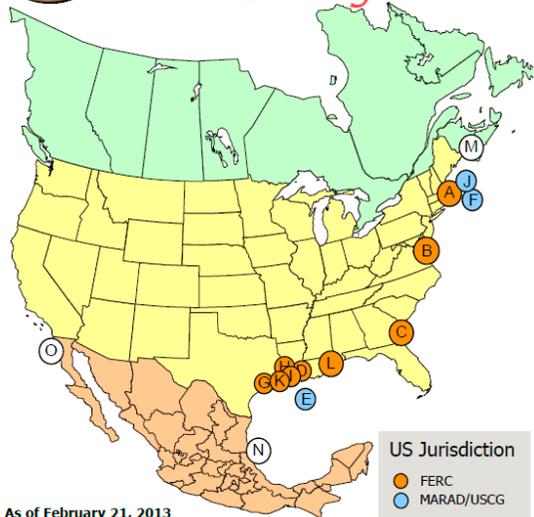
- **Hazards mitigation:**
 - Primary containment – high nickel steel surrounded by 3 foot thick concrete
 - Secondary containment (has never been utilized)
 - Redundant safeguard systems
 - Separation distances (Data Center outside of separation zone)
- **International safety example:**
 - Japan Earthquake – March 2011
 - 28 LNG terminals [1/3rd of world's total]
 - Only one temporarily off-line
 - No other incidents
- **In U.S.:**
 - Highly regulated by several Federal safety agencies for construction and operations
 - Evaluated by Homeland Security Dept. No additional measures needed

Existing LNG Terminals - Global



North American LNG Import/Export Terminals

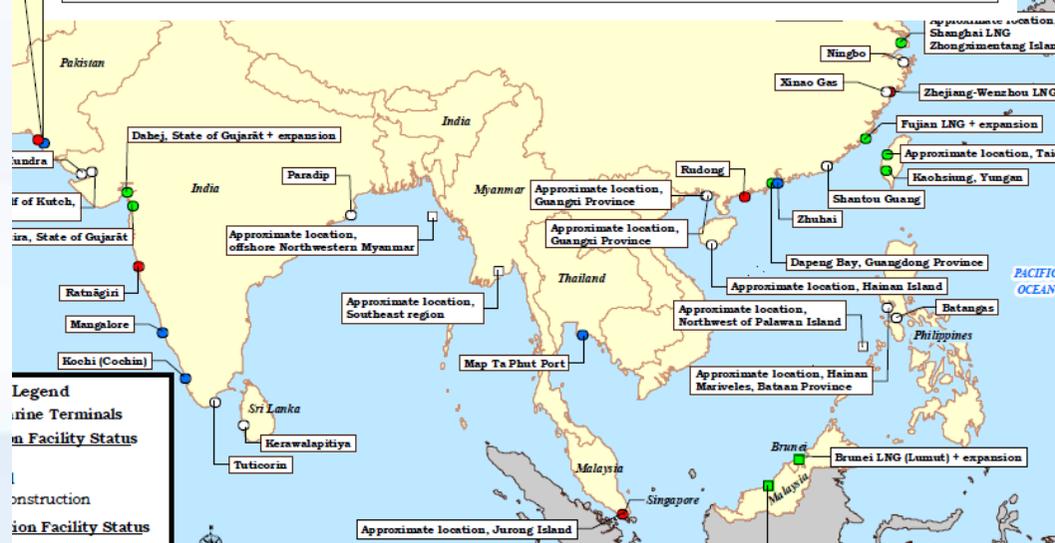
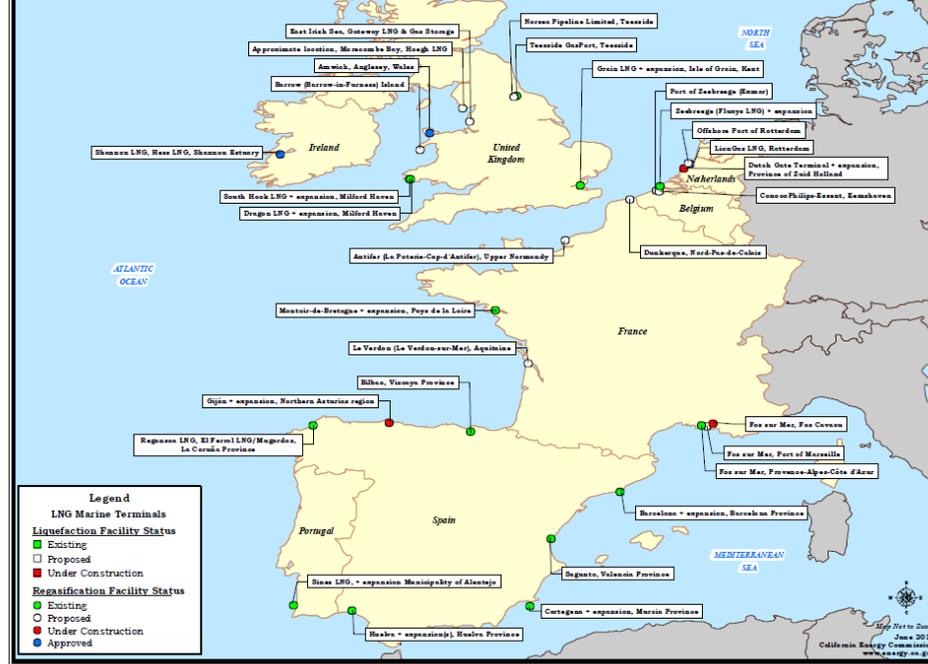
Existing



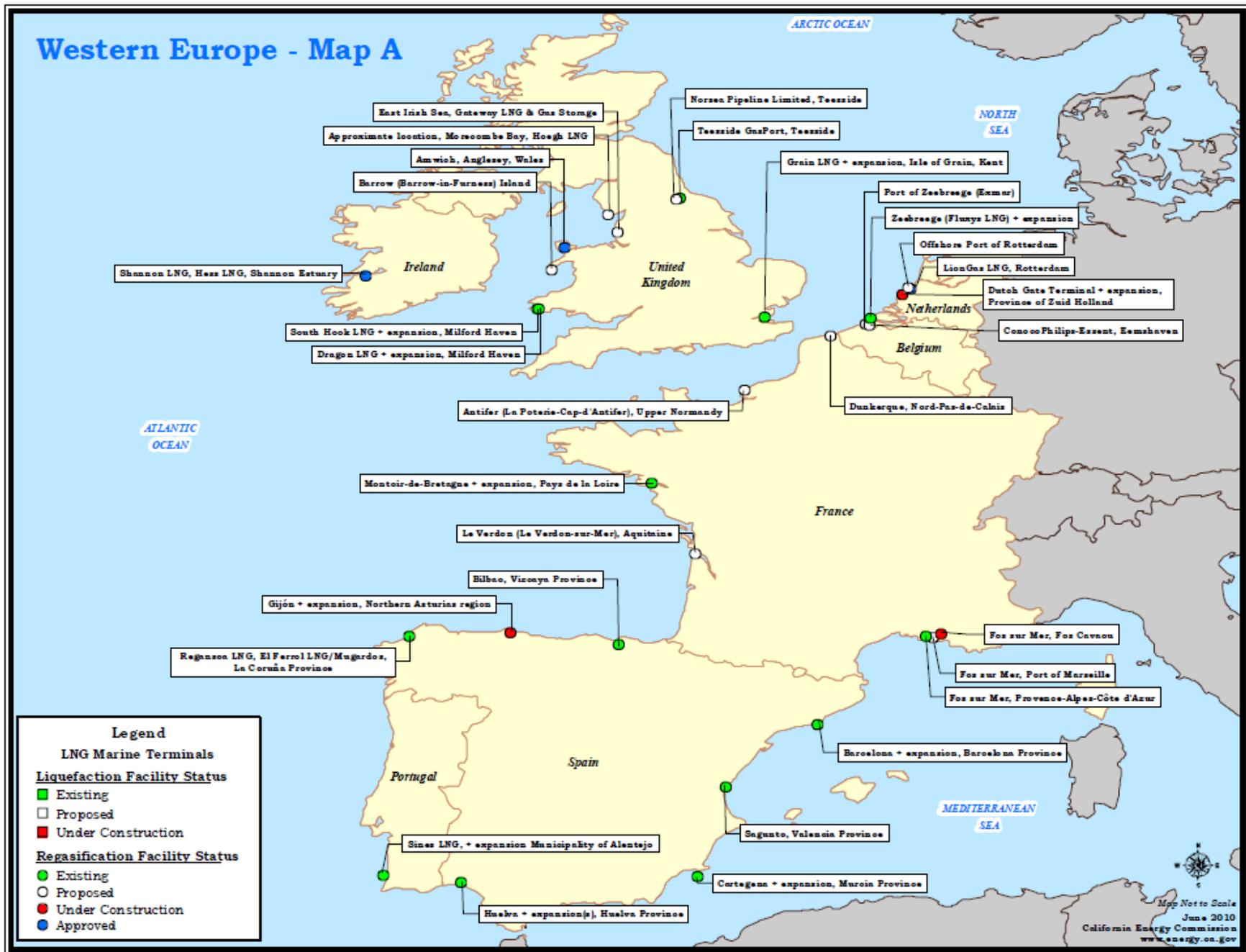
As of February 21, 2013



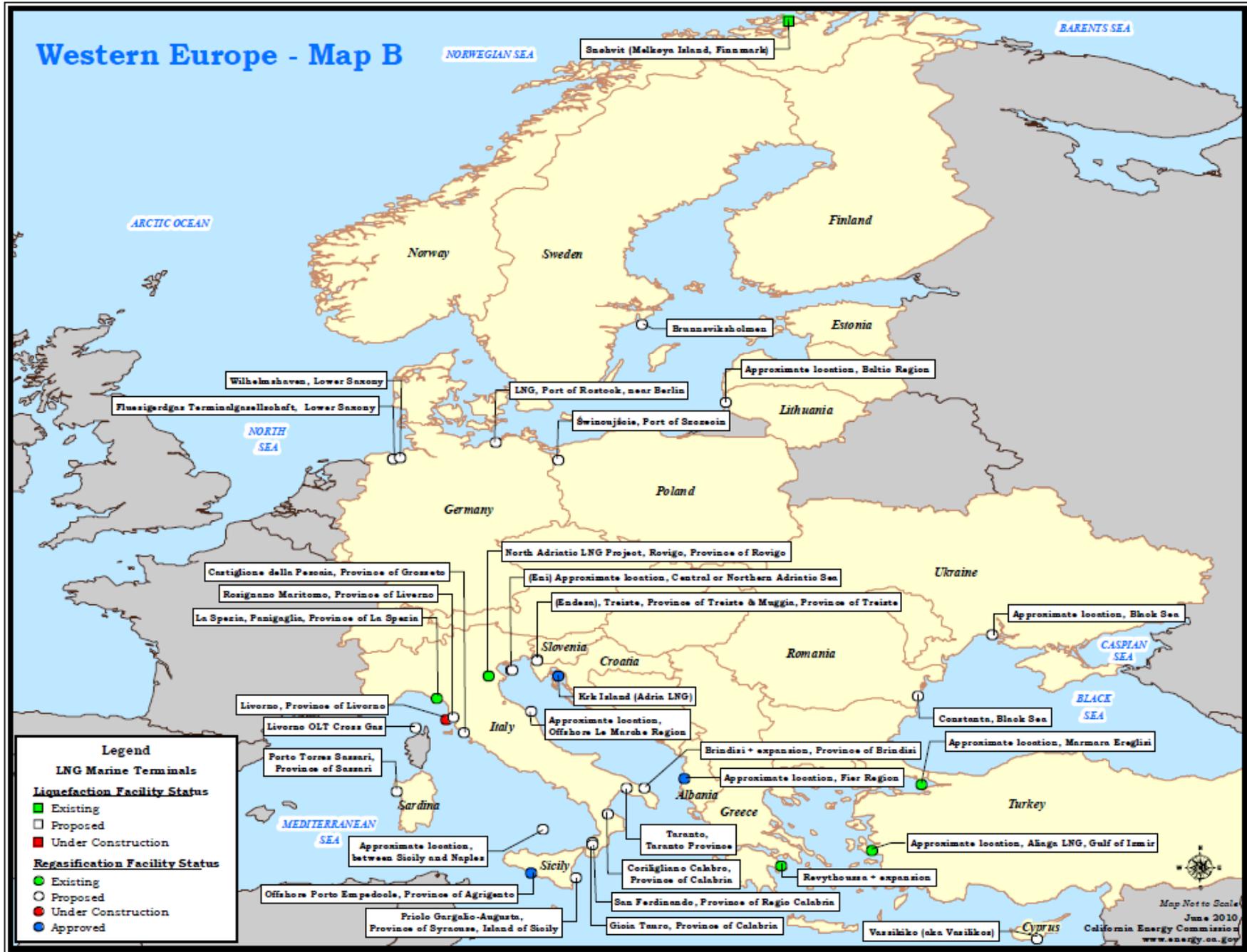
Western Europe - Map A



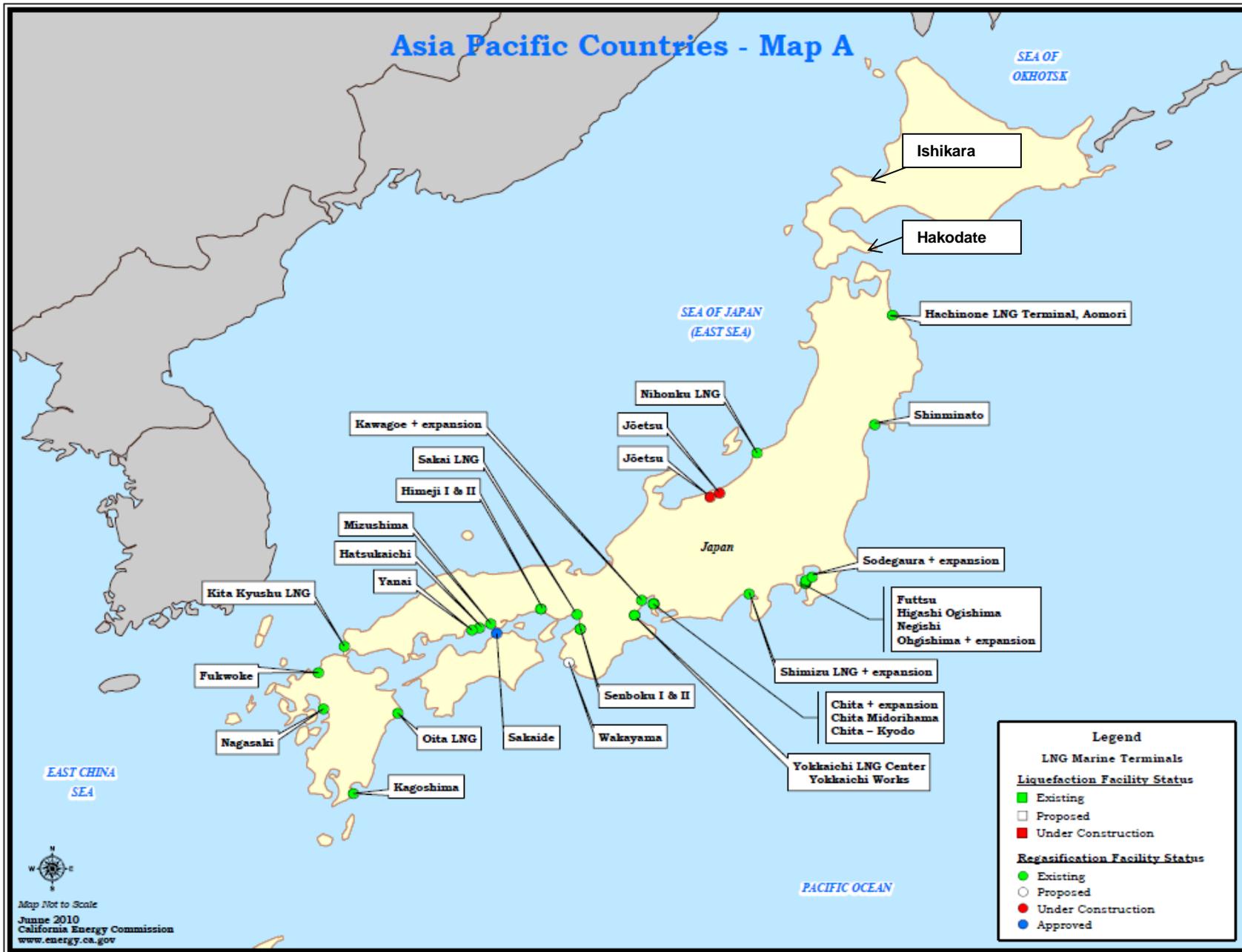
Western Europe – 1 of 2



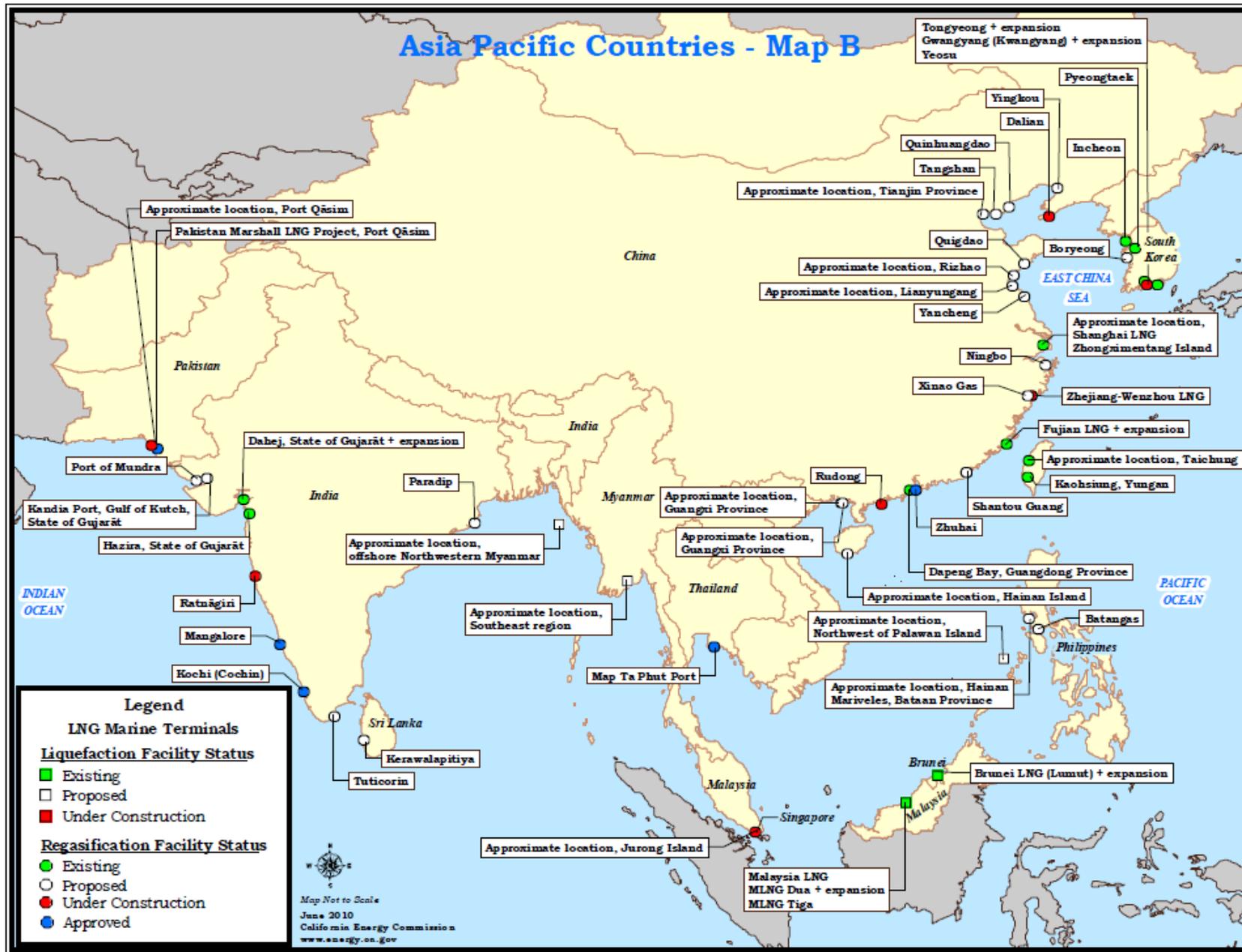
Western Europe 2 of 2



Japan



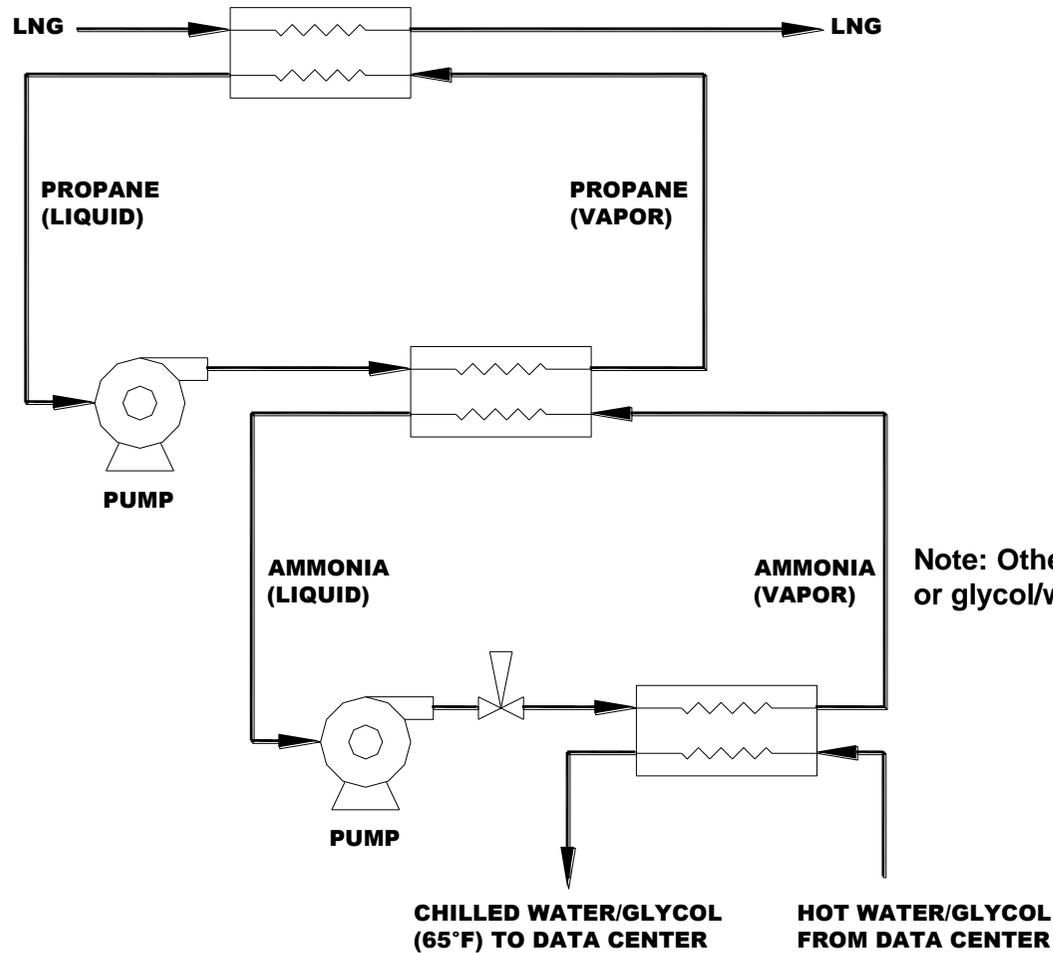
Asia and South Asia



Heat Exchange Process

- **~90% efficient heat exchange refrigeration loop**
- **LNG terminals have enough cold to cool largest data centers**
- **Refrigeration/heat can travel up to two km between facilities**
 - Further separation lowers efficiency and increases costs
- **Patent pending**

Schematic: Heat Exchange



Note: Other non-toxic and non-flammable refrigerants or glycol/water can be used instead of ammonia

Electrical Power Generation

- **Excess refrigeration available at most LNG terminals beyond data center cooling needs**
- **Temperature gradient between LNG and ambient can drive expansion turbines generating non-combustion, zero-emissions electrical power**
 - 2.5 MW and up
 - Japan ~ 45 MW installed capacity at LNG terminals
- **25-30% overall energy efficiency**
- **Patent pending**

Schematic: Heat Exchange + Power Generation

Available via Non-Disclosure Agreement

Case Studies

Singapore – Singapore LNG



France – Fos Cavaou LNG



Portugal – Sines LNG



Case Study Financials – Singapore

Case Study: 30 MW Data Center Example

Data Center Size:	30 MW IT + 10 MW Cooling	
	COOLING ONLY	COOLING + POWER GEN
Capital Costs:*	\$ 9 million	\$ 63.5 million
Gross Annual Savings:	\$ 19.1 million	\$ 75.8 million
Annual Operating Costs:	\$ 2.8 million	\$ 6.4 million
Net Annual Energy Savings:	\$ 16.3 million	\$ 69.3 million
Internal Rate of Return:	187%	116%

- Does not include TeraCool or LNG terminal fees or savings

Case Study Financials – Fos Cavaou, France

Case Study: 30 MW Data Center Example

Data Center Size:	30 MW IT + 10 MW Cooling	
	COOLING ONLY	COOLING + POWER GEN
Capital Costs:*	\$ 7.0 million	\$ 52.4 million
Gross Annual Savings:	\$ 7.3 million	\$ 24.7 million
Annual Operating Costs:	\$ 1.6 million	\$ 4.5 million
Net Annual Energy Savings:	\$ 5.7 million	\$ 20.2 million
Internal Rate of Return:	68%	45%

- Does not include TeraCool or LNG terminal fees or savings

Case Study Financials – Sines, Portugal

Case Study: 30 MW Data Center Example

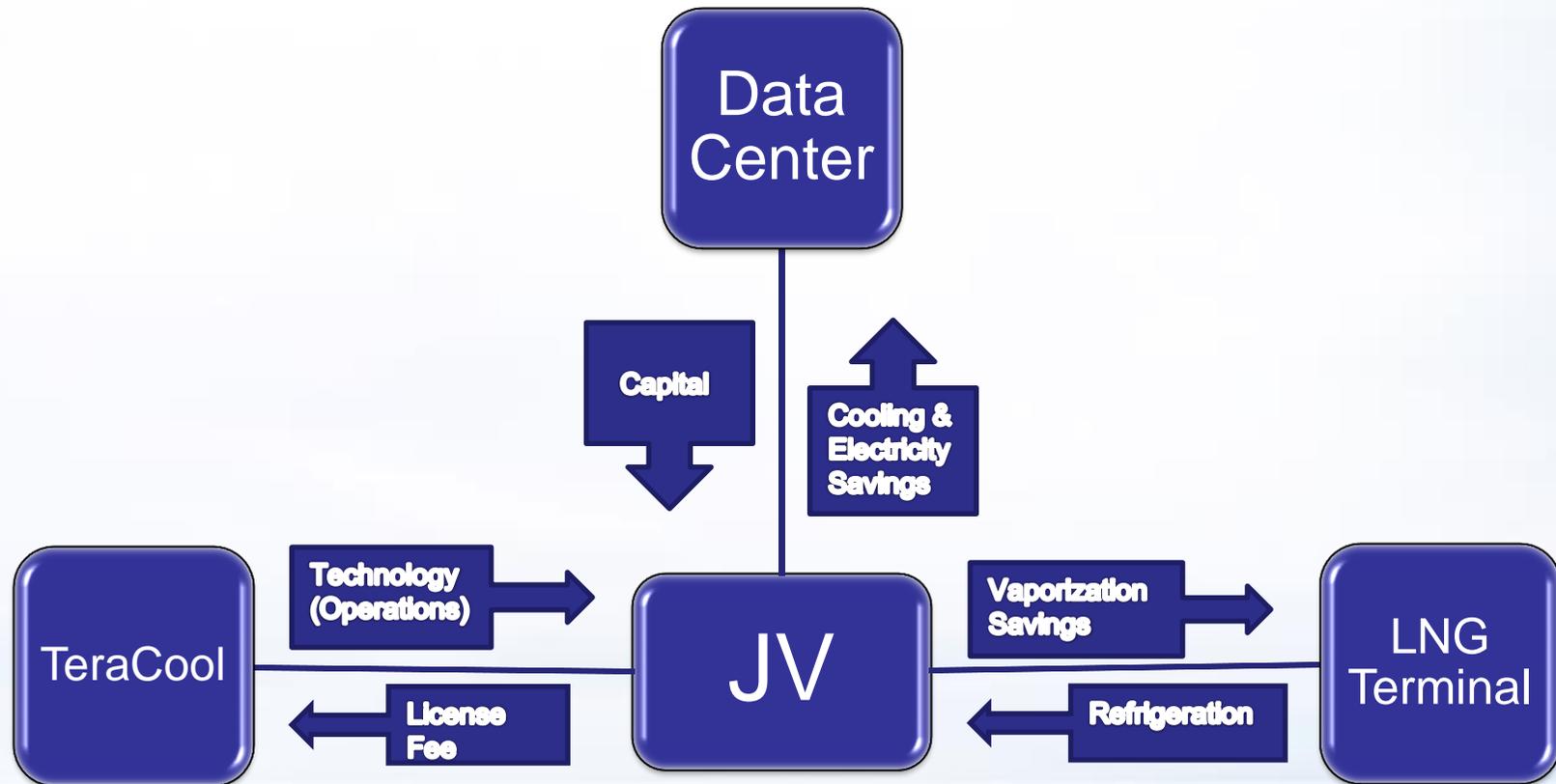
Data Center Size:	30 MW IT + 10 MW Cooling	
	COOLING ONLY	COOLING + POWER GEN
Capital Costs:*	\$ 9 million	\$ 16.8 million
Gross Annual Savings:	\$ 8.4 million	\$ 12.4 million
Annual Operating Costs:	\$ 1.7 million	\$ 2.2 million
Net Annual Energy Savings:	\$ 6.7 million	\$ 10.2 million
Internal Rate of Return:	80%	66%

- Does not include TeraCool or LNG terminal fees or savings

Highest Sustainable Data Center Solution via Industrial Ecology: waste streams = resources

- **Eliminates data center cooling power and can supply nearly 100% of IT power**
 - Uses zero-emissions, expansion turbine power generation
- **GHG reductions from offset power demand:**
 - GHG credits may have significant market value
 - Singapore ~170,000 TPY
 - Equivalent to removing 30,000 cars per year
 - Sines, Portugal ~36,000 TPY
 - Fos Cavaou, France ~25,000 TPY
- **If LNG terminal included, GHG credits can be higher**
 - Additional seawater environmental quality benefits

Potential Business Structure



Progress

- **Discussions ongoing with top ten data center partners**
- **Interest from major LNG terminals for cold recovery in:**
 - U.S.
 - Mexico
 - Chile
 - France
 - U.K.
 - Spain
 - Portugal
 - Taiwan
 - Japan
 - China
 - S. Korea
 - Singapore
 - India
 - Others
- **Potential Fortune 500 strategic partner that services data centers**
- **Request to participate by Singapore EDB in EIO for uses of cold from Singapore LNG - 2014**
- **Participating in Green Grid working groups**
- **Peer reviewed recognition:**
 - International Society of Industrial Ecology – S. Korea 2013
 - Datacentres Europe presentation – France 2013 & Monaco 2014
 - Winner Uptime Institute Green IT *Audacious Idea* Award – 2013

Management Team

Robert Shatten – President

Principal, Boreal Renewable Energy Development; AES; U.S. EPA; Arthur D. Little Inc.; hazardous/radioactive waste recycling startup.

J.D. Jackson – Chief Technology Officer

35+ years in market development/commercializing cryogenic applications for Linde Industrial Gases and Praxair; Member, National Fire Protection Assn. technical standards committee.

Eric Grunebaum – Chief Business Dev't Officer

20+ years experience building enterprises, initiating strategic partnerships, assembling and directing teams, managing projects, developing communications.

MIT Prof. John Brisson – Co-founder/Advisor

Professor of Mechanical Engineering at MIT with over 20 years experience in the fields of fluid mechanics, heat transfer and thermodynamics. Director MIT Cryogenic Engineering Lab.

Joe Grabmeier – CPA|CFO

25+ years experience in senior financial positions in establishing and building emerging companies.



TeraCool Can Achieve Corporate Missions

Facebook

- Our goal is to power all of our operations with clean and renewable energy
- Siting policy states a preference for access to clean and renewable energy

Microsoft

- Instituting a companywide commitment to achieve carbon neutrality
- Long-term capital investment in new renewable energy projects, and data centers with on-site innovative renewable energy sources

Google

- Our efforts in efficiency, buying clean energy, and purchasing offsets bring our carbon footprint down to zero
- We're going beyond carbon neutral by committing over \$1 billion to renewable energy projects that create far more renewable energy for the world than we consume as a company

Yahoo!

- Yahoo! is committed to being an environmentally responsible company
- Pushing the industry standards for energy-efficiency in data centers

Amazon Web Services

- Corporate goal to offer services in:
 - “an environmentally friendly way in all of our regions”
- Amazon employees at all levels dive deep to identify waste and design alternative solutions that are more energy efficient.

Audacious or Consistent with Corporate Mission?

Digital Realty Trust

- DRT has made sustainability and energy efficiency a central focus of how we design, build and operate our datacenter facilities

Rackspace

- Incorporate energy conservation & efficiency into decision making in the way we build, buy and operate
- Committed to providing the world with access to the most efficient infrastructure designs
- We weight facility-siting investments that avoid the use of power and/or rely primarily on renewable energy as a source of electricity over those that do not

eBay

- Committed to accelerating more sustainable, more vibrant commerce
- Core belief that a rapid transition to a 21st century, low-carbon economy will create new jobs and stimulate economic growth while stabilizing our planet's fragile climate
- Our opportunity is to think about the role sustainability plays in that future — and how we can advance it through engaging people, building a greener company, embedding sustainability into commerce, and shaping the industry.
- Driving efficiency and sustainability across every facet of our business operations.

Next Steps

- **Preserve TeraCool IP in Japan?**
- **Multi-site Feasibility Study ?**
- **Strategic partnership?**

Contact Information

Bob Shatten

President, TeraCool LLC

Cell: 617.905.5757

bob@teracool-llc.com

Concord, Massachusetts