The Global LNG Market – An Option for Europe?

Supply Security in International Natural Gas Markets and the Effects of Expanding the Panama Canal on LNG Flow

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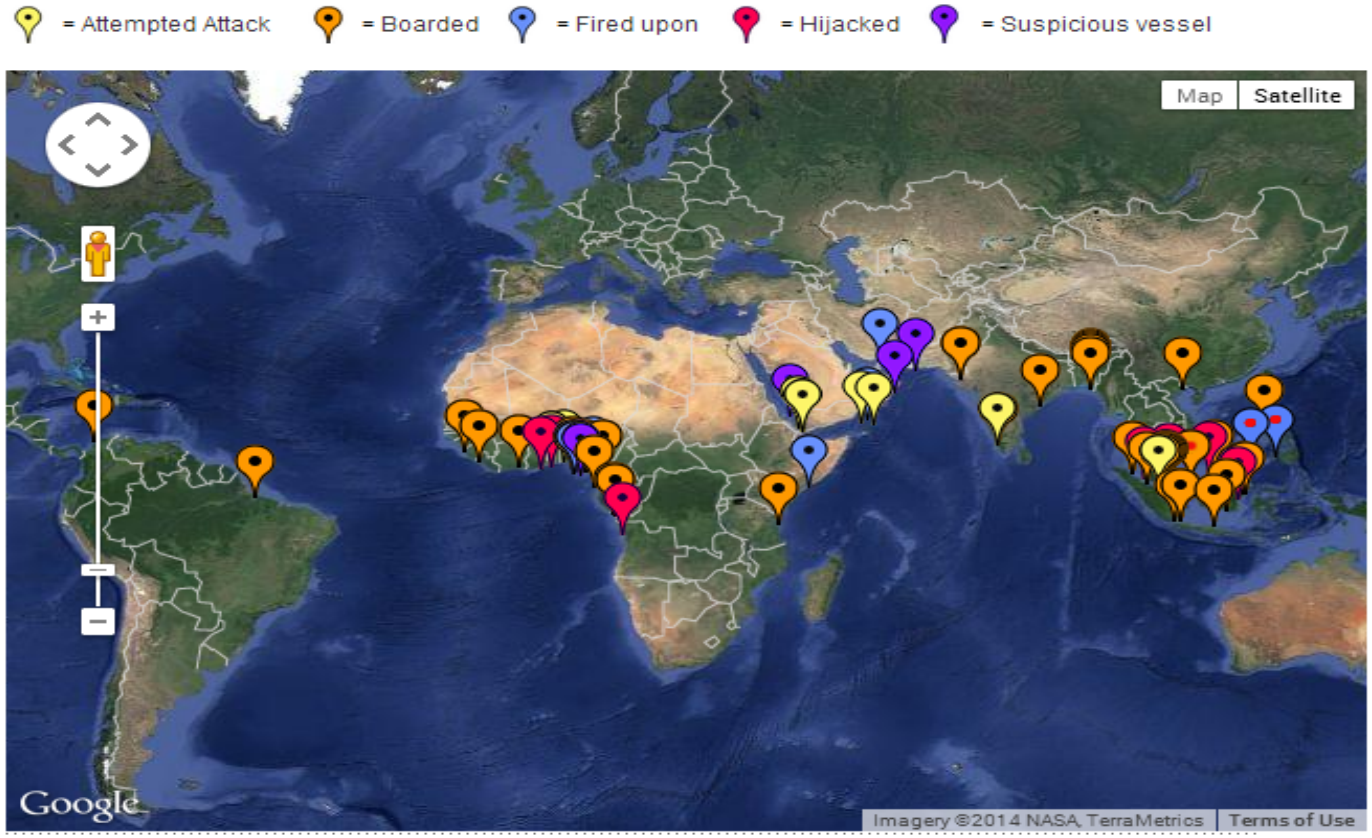
Outline

Presentation Overview

- Energy security/International natural gas markets
- World Gas Model (WGM)
  - Case Study for Natural Gas using the WGM (2012)
  - Assumptions/references used in this study
  - World Gas Model (2012)- Base Case summary
  - WGM scenarios
  - Results/Analyses for 6 Scenarios (Sensitivity Analysis for Canal tolls)
- Conclusions and Future Work

Vulnerability of transport routes: IMB piracy map 2013



- The incidents happened around four major checkpoints, Suez Canal the Bab El Mandeb, the Strait of Hormuz, and Malacca

1:IMB stands for International Maritime Bureau

2. LNG tankers become the target. The bad thing is that if the tanker sank in the main waterway e.g., Suez Canal, it would very hard to get it back. It will be stuck in the waterway for a while : e.q., a week or more. for more details see:

http://www.maritime-executive.com/article/lng-tanker-becomes-target-of-pirate-attack-shots-fired

http://www.lngworldnews.com/pirates-attack-lng-tanker-offshore-oman/

Gas import dependency in Central and South-Eastern Europe (2013)

Country	Gas import dependency	Share of Russia in gas imports	Share of Russia in consumption
Slovenia	100.0%	60.2%	60.2%
Greece	100.0%	55.6%	55.6%
Slovakia	98.4%	83.5%	82.2%
Czech Republic	98.0%	58.6%	57.5%
Bulgaria	97.7%	100%	83.3%
Italy	88.5%	32.6%	28.9%
Austria	78.9%	76.1%	60.0%
Hungary	78.2%	100.0%	78.2%
Poland	72.0%	81.3%	58.6%
Croatia	34.5%	N/A	N/A
Romania	24.3%	100.0%	24.3%
Average	79.1%	68.0%	53.5%

Source: Eurogas

How to achieve natural gas supply security?

- Increase of natural gas infrastructure e.g., storage
- Diversity of suppliers
- Flexibility to shift fuels
- Long-term contracts
- Shale gas development
- Expansion of natural gas grid
- Increased flexibility: LNG from spot market

The European Gas Market- Overview

Trend

- 58% of EU gas LTCs under oil indexation
- Increase in STCs
- Form liberalized markets and move away from oil index prices

Infrastructure

- SoS concerns:
  - New pipeline projects
    - Nord Stream
    - South Stream
    - Southern Corridor
  - New LNG importing terminals
    - Swinoujscie (Poland)
    - Dunkirk LNG (France)
  - Floating Terminals
    - Klaipeda LNG (Lithuania)
    - Livorno (Italy)

Pricing

- 9 main trading hubs
- Highly correlated prices
- Gas prices tied to oil indexation

Supply/Demand

- Indigenous production is decreasing
- The total supply potential is sufficient until 2020ies
- Gas imports to Europe come from four main sources: Norway, Russia/Central Asia, North Africa, LNG
- Slow demand growth

Picture source: http://www.worldatlas.com/webimage/countrys/eu.htm

European Natural Gas Pipeline-Competing Projects

Source: The economist

- Four pipeline projects compete against each other (TANAP-TAP-TIGI-Nabucco) to bring gas from Central Asia to Europe
- Nabucco shareholders now believe that only a smaller version of the pipeline is realistic
- Russia aims to build second Baltic sea pipeline to increase supply to Europe as well as to bypass Ukraine

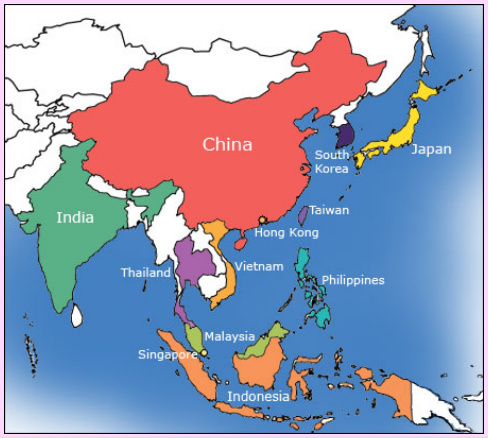
The Asian Gas Market- Overview

Supply/Demand

- S.E.Asia will increase demands for gas due to declining production after 2020
- Asia imports(209 bcm) almost four times more LNG than Europe (60 bcm) (GIIGNL 2013)
- Nuclear disaster changes the demand outlook for LNG (IGU,2013)
- China starting to develop domestic shale gas and set prominent targets for future production (Chou, 2013)

Infrastructure

- Myanmar-China Pipeline
- Singapore, Thailand, Pakistan, Bangladesh, Vietnam, New Zealand , and the Philippines have announced plans to construct regasification terminals (IGU, 2013)
- Australia increases its LNG export capacity, will complete by 2020



Pricing

- Oil indexation is dominant in Asia, more than 88% (Wholesale Price Survey, 2013)
- Government regulations to a large extent continue to determine natural gas prices

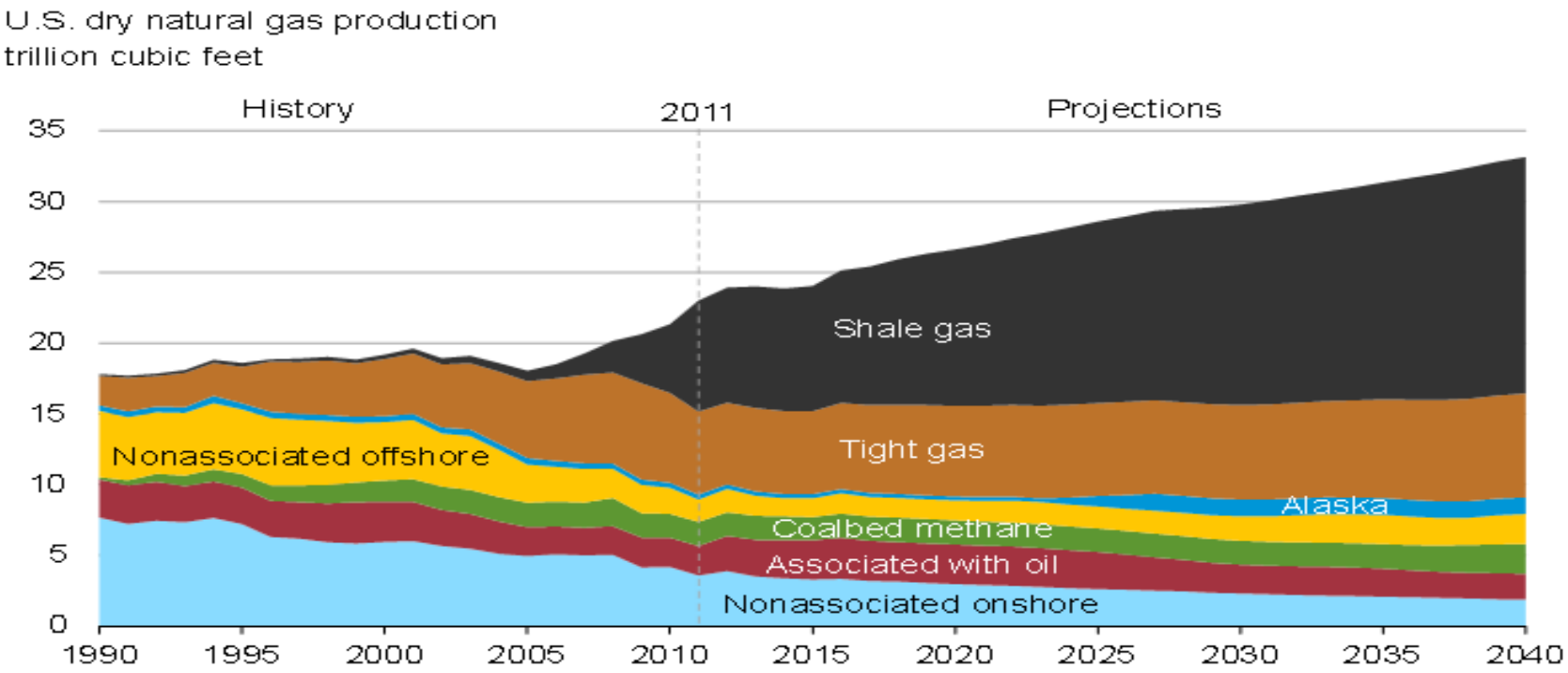
Trend

- Singapore wants to be regional natural gas trading hub
- The Chinese government has looked at ways to introduce more flexible pricing schemes in some developed gas market areas on the east coast.

Picture source:http://www.worldatlas.com/webimage/countrys/eu.htm

North American Gas Market - Shale Gas Revolution

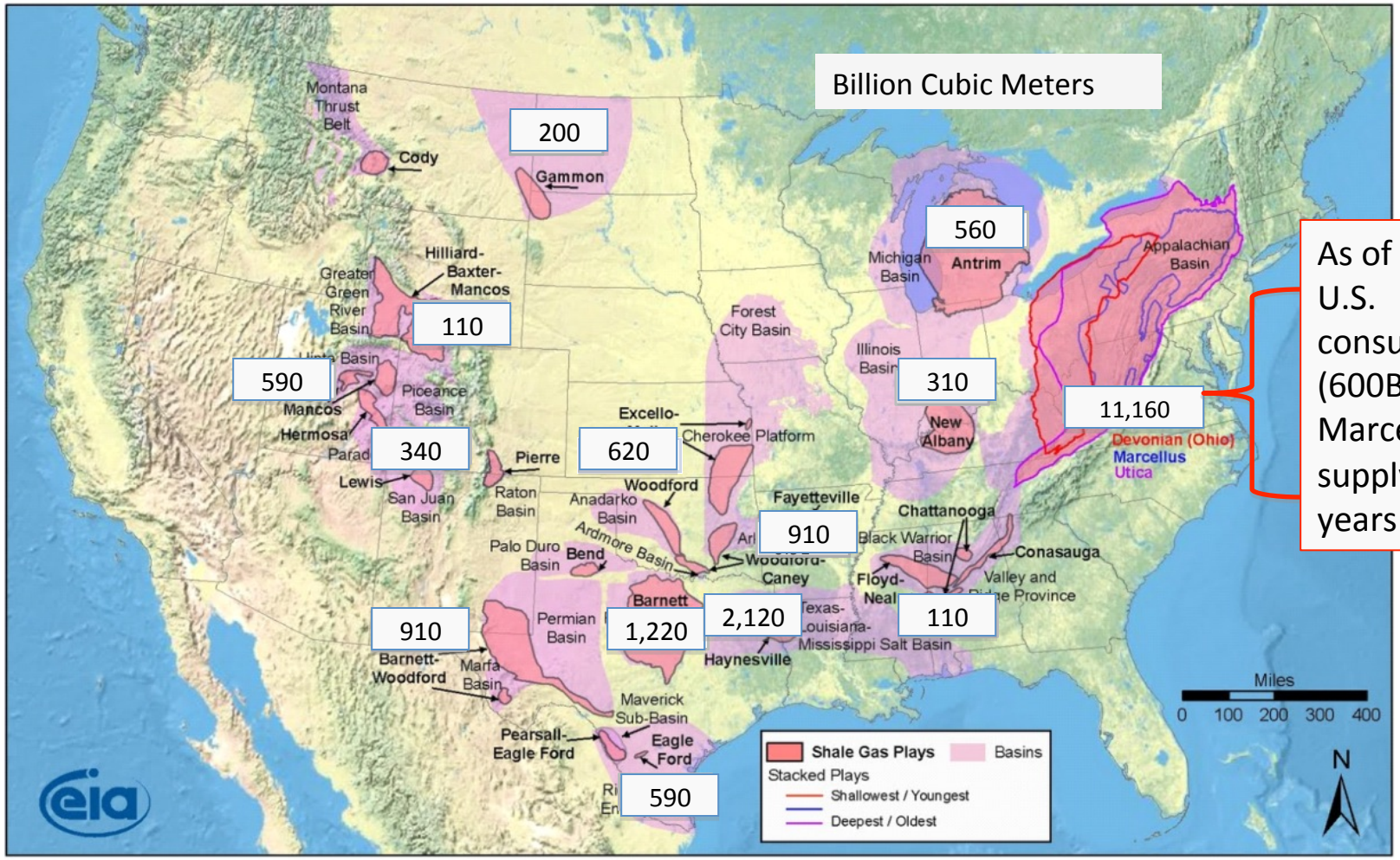
U.S. Shale Gas Production Through 2040 (TCF)



Source: EIA, Annual Energy Outlook 2013 Early Release

- The share of the U.S. shale gas in the total production is increasing
- U.S. LNG exports rise to approximately 1.6 trillion cubic feet in 2027
- The United States becomes a net exporter of LNG in 2016
- Hydrofracking environmental issue by U.S. State

US Shale Gas Plays, Lower 48 States



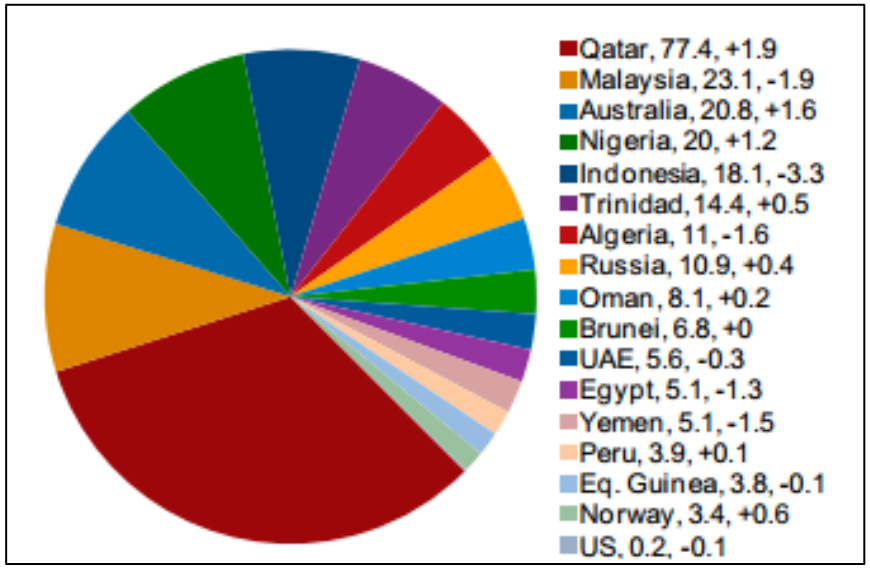
As of 2010 U.S. consumption (600BCM*), Marcellus can supply for 20 years

Source: Energy Information Administration based on data from various published studies
Updated: May 28, 2009

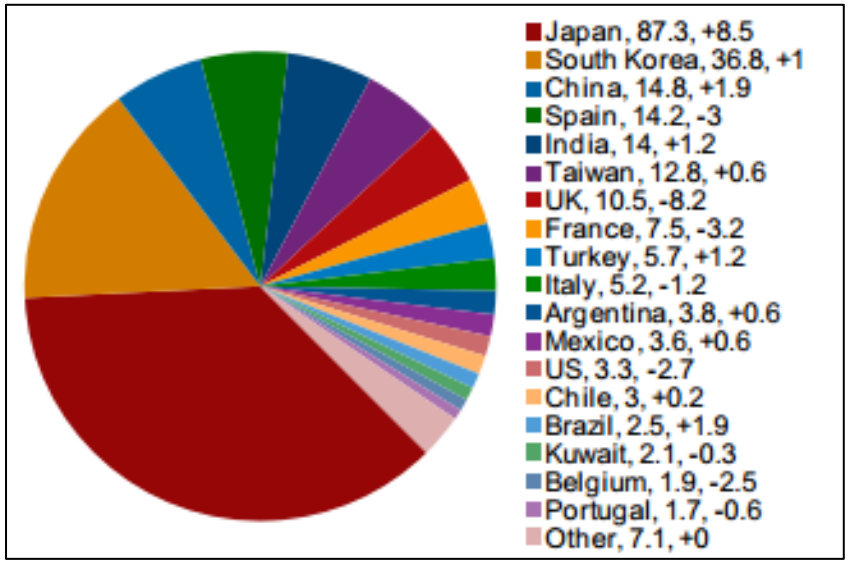
*BP Statistical Review, 2011

LNG Markets- Overview

Overview of LNG Markets (2012) in MTPA and Change related to 2011



LNG Exports in MTPA by Countries

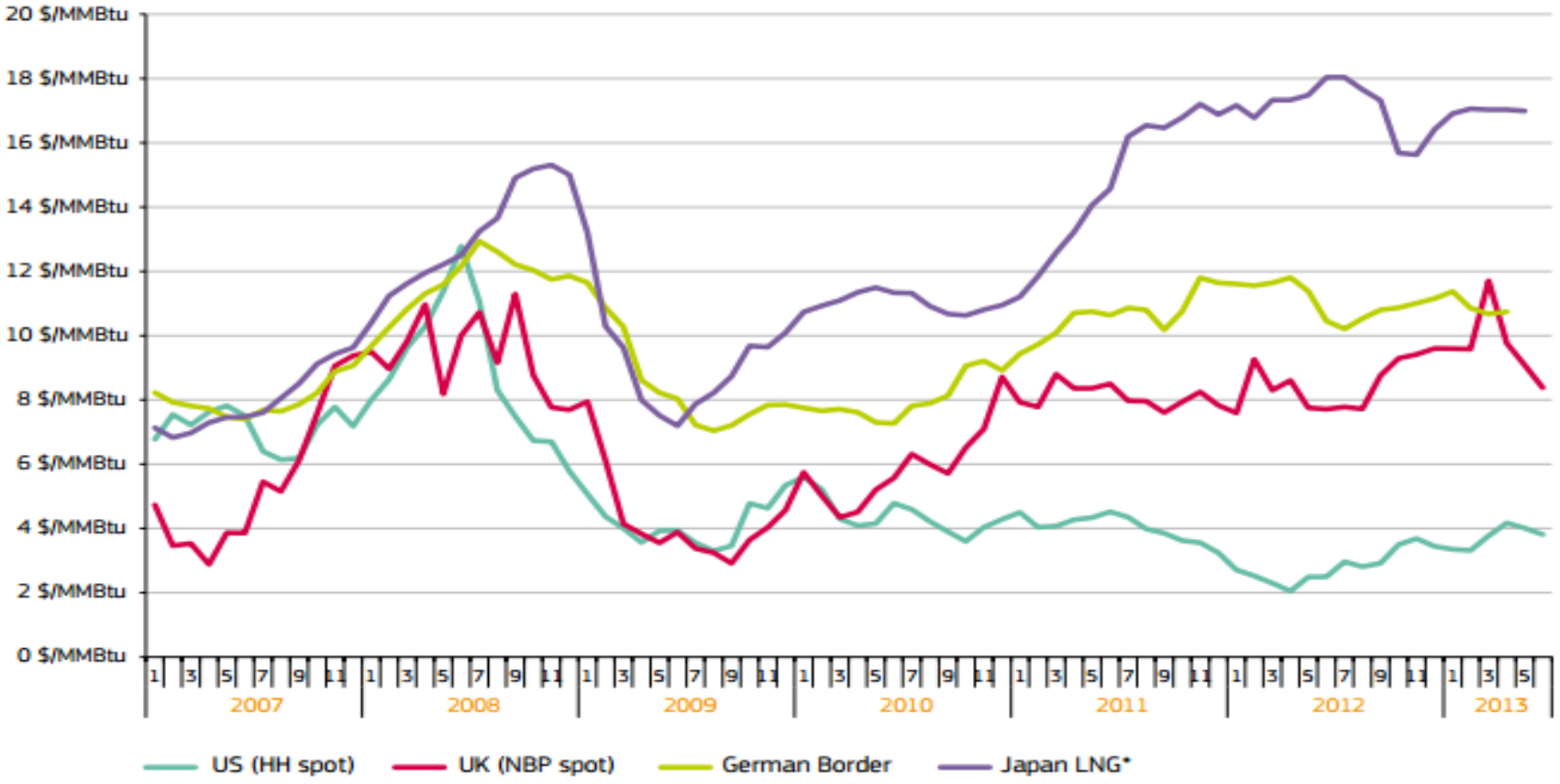


LNG Imports in MTPA by Countries

- Japan and South Korea imported 52% of all LNG in 2012
- One-third of LNG in 2012 is supplied from Qatar
- Qatar, Australia, and Nigeria contributed more than 75% of total supplies

Source: Energy Information Administration,2011

International Comparison of Wholesale Gas Prices



Source: European Commission,2013

- LNG prices in Japan over the first four months of 2013 were on average 55-70% above NBP and German border prices and four and a half times higher than US Henry Hub prices.

U.S. LNG Export Status As of March 5, 2014

	Total of all applications	Approved	Pending
FTA application	38.50 Bcf/d (377.4Bcm/y)	37.80 Bcf/d (370.3 Bcm/y)	0.7 Bcf/d (7.1 Bcm/y)
Non-FTA application	35.58 Bcf/d (348.5 Bcm/y)	9.7 Bcf/d (95.03 Bcm/y)	25.88 Bcf/d (253.56 Bcm/y)

About 31% of LNG trade in 2012

FTA with the U.S. requires national treatment for trade in natural gas, including Australia, Bahrain, Canada, Chile, Colombia, Dominican Republic, El Salvador, Guatemala, Honduras, Jordan, Mexico, Morocco, Nicaragua, Oman, Peru, Republic of Korea and Singapore

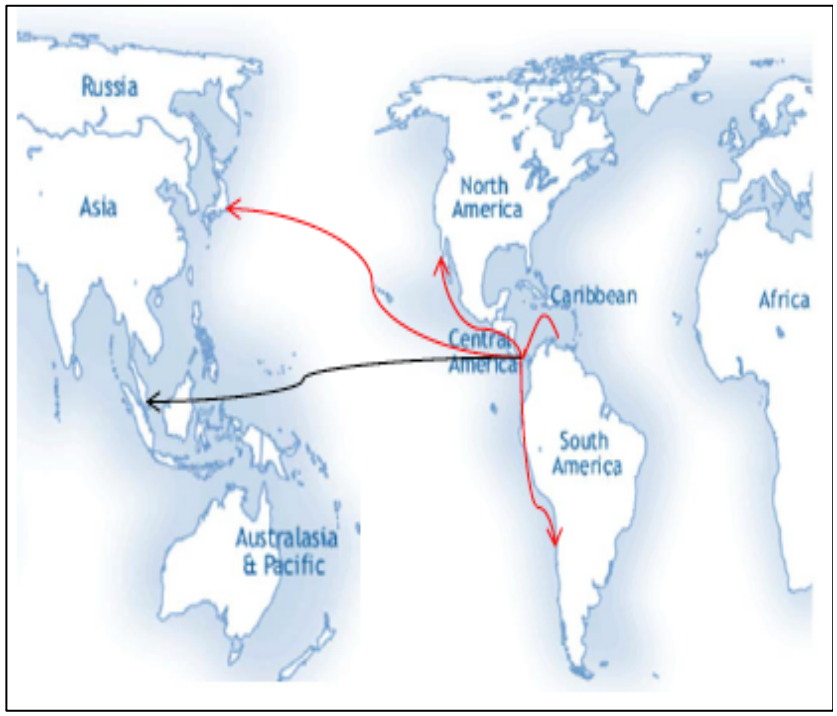
http://energy.gov/sites/prod/files/2013/08/f2/Summary_of_Export_Applications.pdf

Source: U.S. Department of Energy

Consider Distances in Nautical Miles for LNG Exports from LNG Exporting Countries

Origin	Via Panama	Via Suez	Around Cap Horn	Around Good Hope	Destination
Gulf of Mexico	3,733	21,637	9,783	19,713	Mexico West
	4,449	19,723	13,476	20,266	Chile
	9,756	14,449	17,060	15,697	Japan
	12,147	11,910	16,900	13,157	Singapore
Trinidad	3,331	20,272	7,643	17,573	Mexico West
	4,048	18,358	11,336	18,126	Chile
	9,355	13,054	14,920	13,557	Japan
	11,746	10,545	14,761	11,027	Singapore
Norway	7,471	19,474	10,801	19,601	Mexico West
	8,188	17,559	14,493	20,155	Chile
	13,494	12,285	18,078	15,585	Japan
	15,886	9,746	17,918	13,046	Singapore

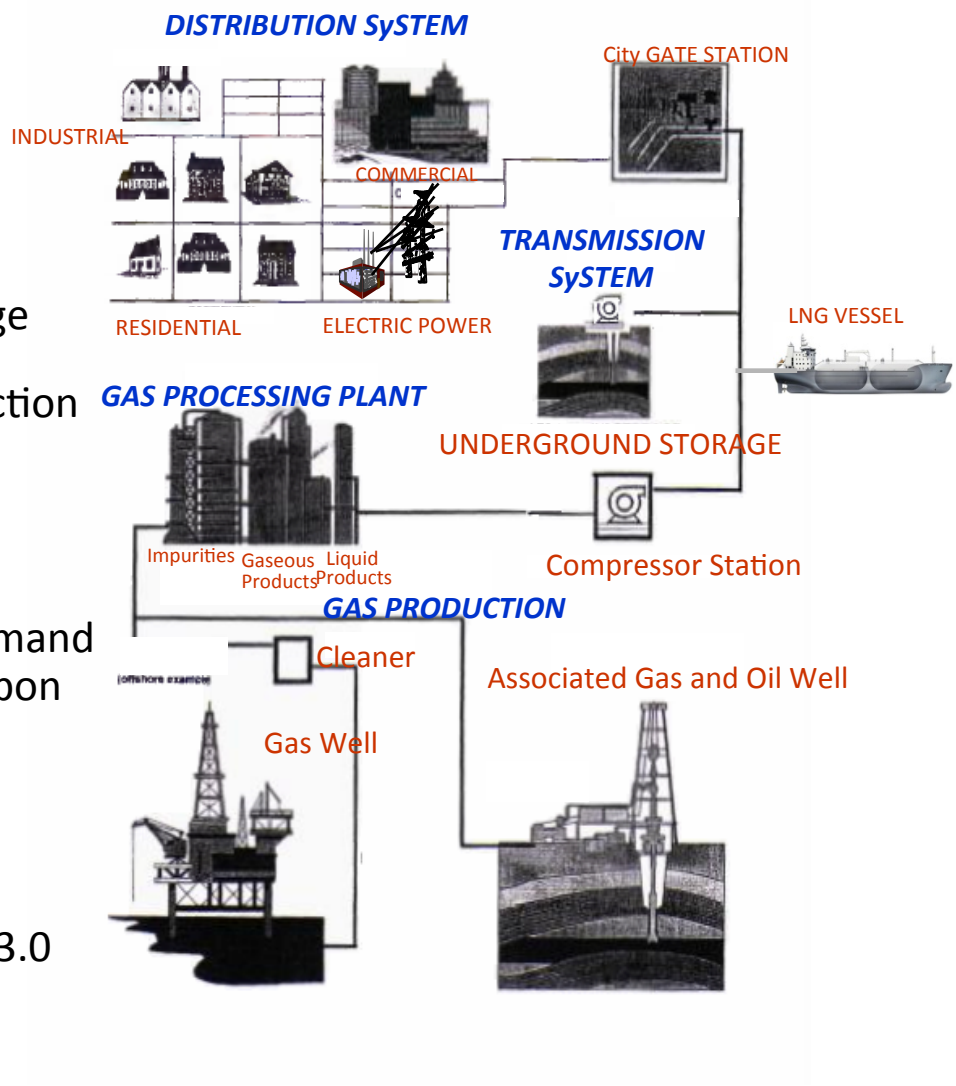
Popils,2011



- Massive time saving on voyages to Japan, South Korea, Japan, Taiwan and China
- Avoid Cape Horn during winter season for potential deliveries to Western coast of North and Central America
- Panama Canal expansion will allow more ships (LNG included) to use the route

The World Gas Model, Large-Scale Mixed Complementarity Market Equilibrium Model Based On Nash-Cournot

- Production/Consumption Nodes: 41 (Groups of countries, countries, regions)
- Covers over 95% of worldwide consumption
- 10 periods: 2005-2050, calibration year 2010
- Typical decision variables
  - Operating levels (e.g., production, storage injection)
  - Investment levels (e.g., pipeline, liquefaction capacity)
- Other
  - Market power aspects (traders)
  - LNG contracts database
  - Seasonality of demand: low and high demand
  - Environmental policy consideration: Carbon costs for supply chains
- Computational aspects
  - Large-scale complementarity problem (optimization conditions for all players + market-clearing conditions)
  - ~78,000 vars. Solves in ~240 mins (8GB, 3.0 GHz)



Selected market player: Producer Optimization Problem

Revenue

Production Cost

$$\max_{SALES^P_{pdm}} \quad \sum_{m \in M} \gamma_m \sum_{d \in D} days_d \left[\pi^P_{n(p)dm} SALES^P_{pdm} - c^P_{pm}(SALES^P_{pdm}) \right]$$

$$s.t. \quad SALES^P_{pdm} \leq \overline{PR}^P_{pm} \quad \forall d, m \quad \left(\alpha^{PR}_{pdm} \right)$$

Production Capacity

$$\sum_{m \in M} \sum_{d \in D} days_d SALES^P_{pdm} \leq \overline{PH}_p \quad \forall m \quad \left(\alpha^{PH}_p \right)$$

Reserve Limitation

$$SALES^P_{pdm} \geq 0 \quad \forall d, m$$

- Producers maximize their profit
- WGM distinguishes three type of producers for North America (Conventional, Shale, non-shale unconventional)
- Cost function (Golombek Cost function) differs for each producer

Selected market player: Trader Problem

$$\max_{\substack{SALES^T_{tndm} \\ PURCH^T_{tndm} \\ FLOW^T_{tadm} \\ INJ^T_{tndm} \\ XTR^T_{tndm}}} \sum_{m\in M}\gamma_m \sum_{d\in D} days_d \left\{ \sum_{n\in N(t)} \left[\begin{array}{l} \left(\delta^C_{tn}\Pi^W_{ndm}(\cdot)+(1-\delta^C_{tn})\pi^W_{ndm}\right) SALES^T_{tndm} \\ -\pi^P_{ndm} PURCH^T_{tndm} \\ -\sum_{s\in S(t)} \left(\begin{array}{l} \left(\tau^{SI,reg}_{sndm}+\tau^{SI}_{sndm}\right) INJ^T_{tndm} \\ +\quad \tau^{SX}_{sndm} XTR^T_{tndm} \end{array} \right) \end{array} \right] - \left(\sum_{a\in A(t)} \left(\tau^{A,reg}_{adm}+\tau^A_{adm}\right) FLOW^T_{tadm} \right) \right\}$$

Revenue

Natural Gas Cost

Storage Cost

Transport Cost

$$s.t. \quad PURCH^T_{tndm} + \sum_{a\in a^+(n)} (1-loss_a) FLOW^T_{tadm} + XTR^T_{tndm} =$$

$$SALES^T_{tndm} + \sum_{a\in a^-(n)} FLOW^T_{tadm} + INJ^T_{tndm} \quad \forall n,d,m \quad \left(\varphi^T_{tndm}\right)$$

Mass Balance constraint

$$(1-loss_s)\sum_{d\in D} days_d INJ^T_{tsdm} = \sum_{d\in D} days_d XTR^T_{tsdm} \quad \forall n, s\in S\left(N(t)\right), d, m \quad \left(\varphi^S_{tsdm}\right)$$

Storage Cycle Con

$$FLOW^T_{tadm} \geq CON^T_{tadm} \quad \forall a,d,m \quad \left(\varepsilon^T_{tadm}\right)$$

Contractual obligations

$$SALES^T_{tndm} \geq 0 \quad \forall n,d,m$$

$$PURCH^T_{tndm} \geq 0 \quad \forall n,d,m$$

$$FLOW^T_{tadm} \geq 0 \quad \forall a,d,m$$

$$INJ^T_{tndm} \geq 0 \quad \forall n,d,m$$

$$XTR^T_{tndm} \geq 0 \quad \forall n,d,m$$

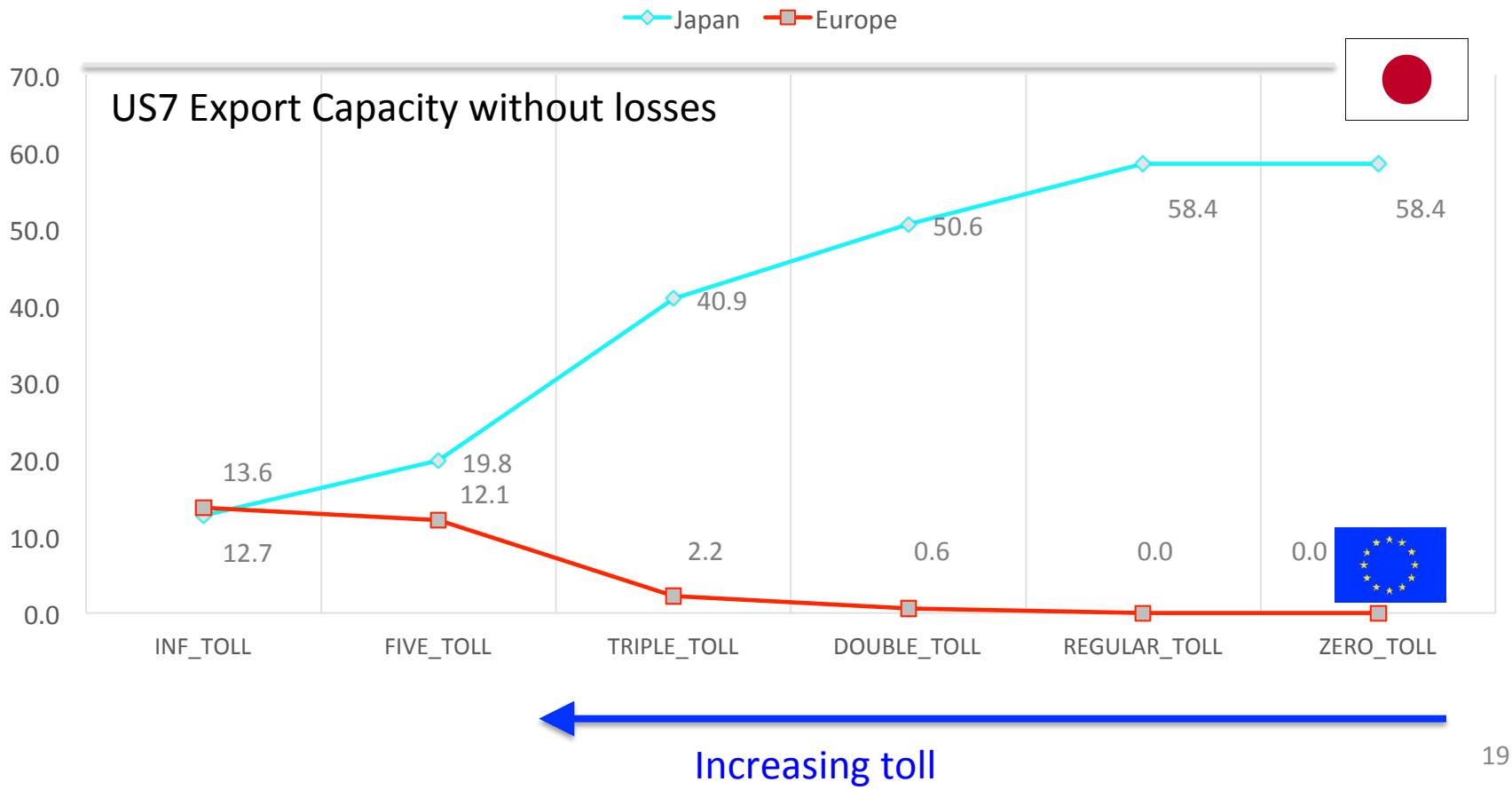
Trader

- Buys gas from producer
- Exerts market power
- Controls usage of storage
- Responsible for regulated and congestion fee

EDF-WGM Sensitivity Analysis Scenarios

Scenarios	Assumptions
Zero_Toll	"Zero Tariff" :tariff is 0$/trip
Regular_Toll	"Regular Tariff" : Canal Tariff tariff = $/trip or $0.35 /MMBtu
Double_Toll	“Double Tariff” :Canal tariff=Regular tariff X 2 o= $0.70 /MMBtu
Triple_Toll	“Triple Tariff” :Canal tariff=Regular tariff X 3 = $1.05 /MMBtu
Fivefold_Toll	“Fivefold Tariff” :Canal tariff=Regular tariff X 5= $1.75 /MMBtu
Inf_Toll	"Infinite Tariff” : Canal tariff= large number 9,999$/kcm

Impacts of Canal Tolls on Flows from US Gulf of Mexico (US7 Node)



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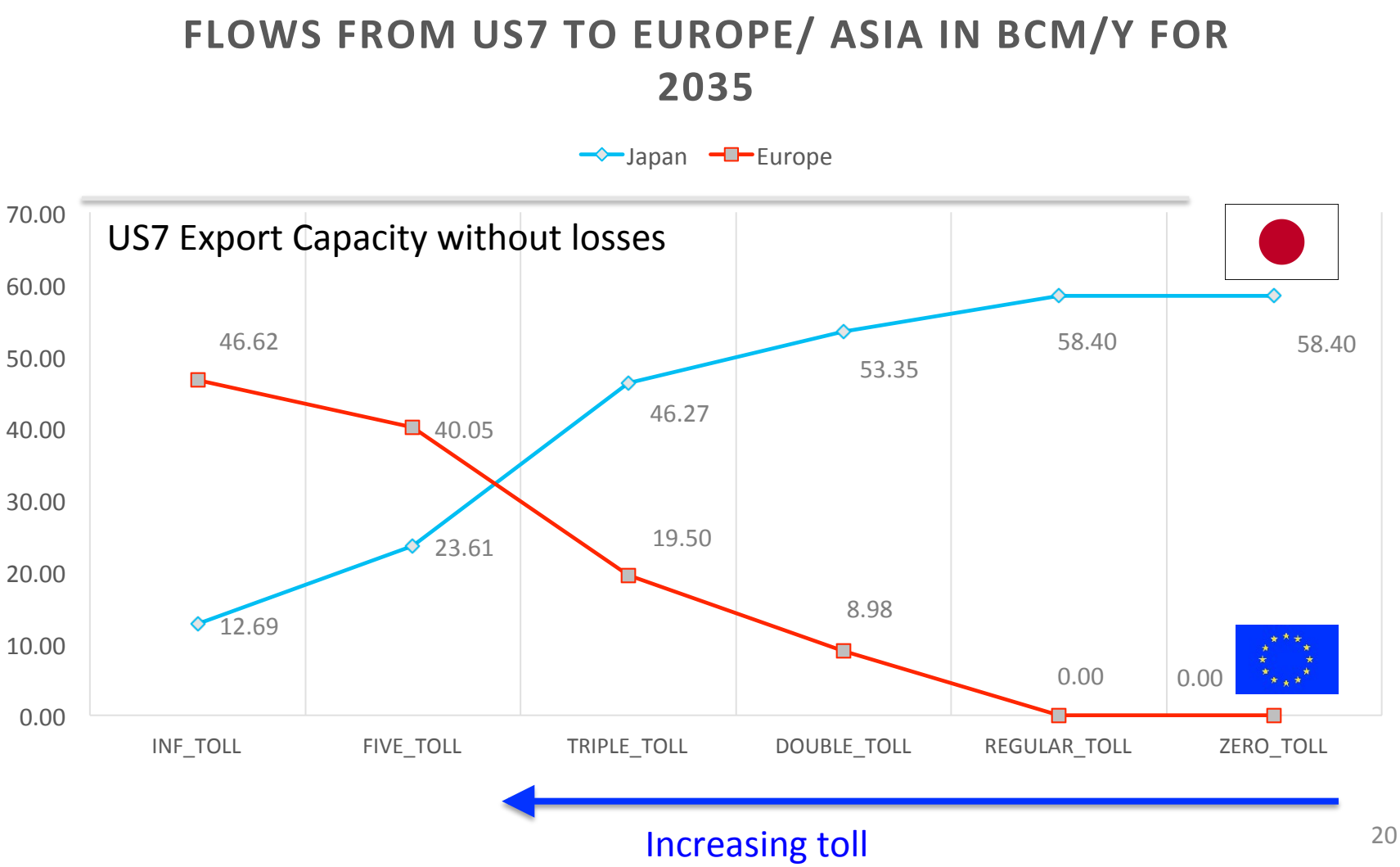
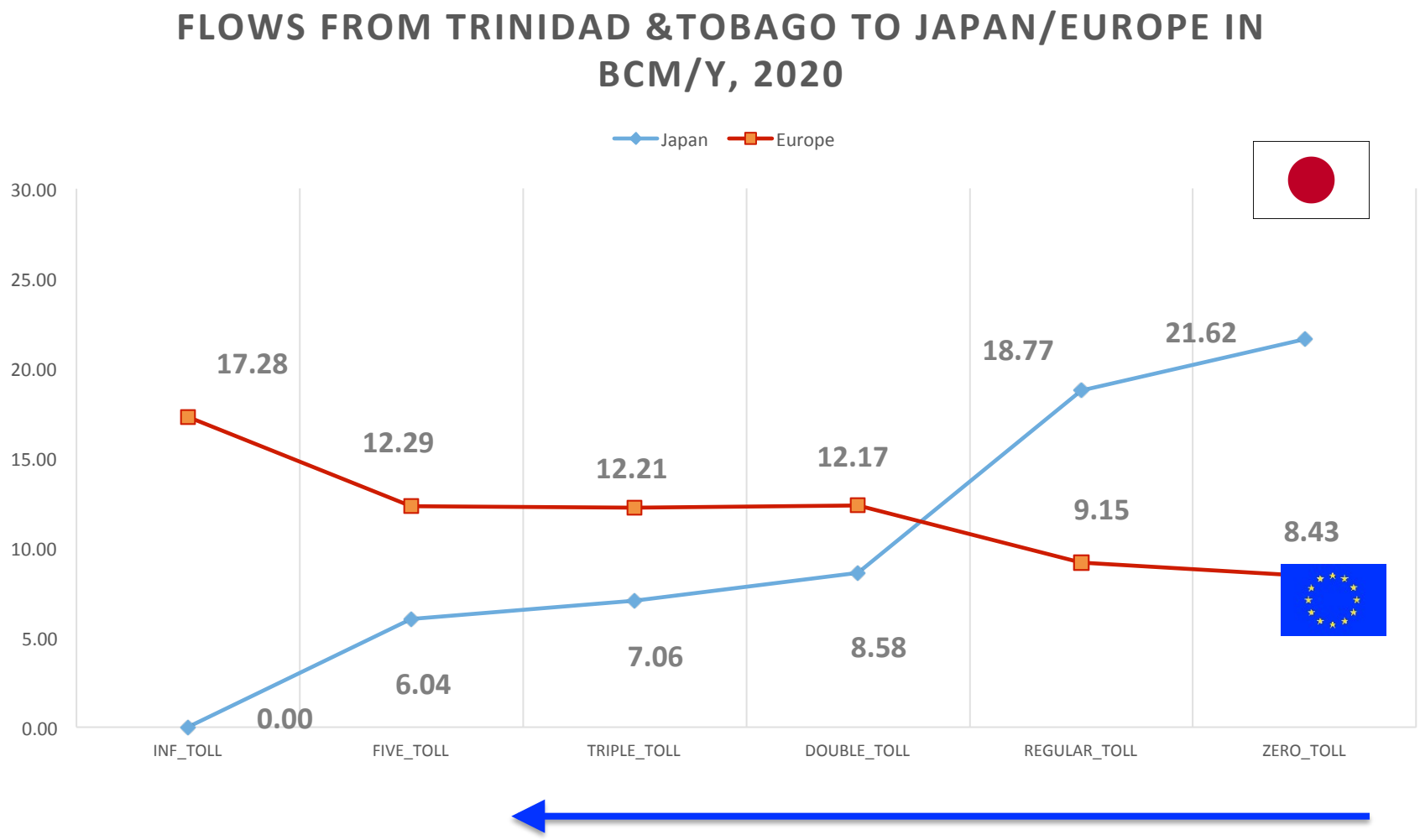


Impacts of Canal Tolls on Flows from Trinidad & Tobago



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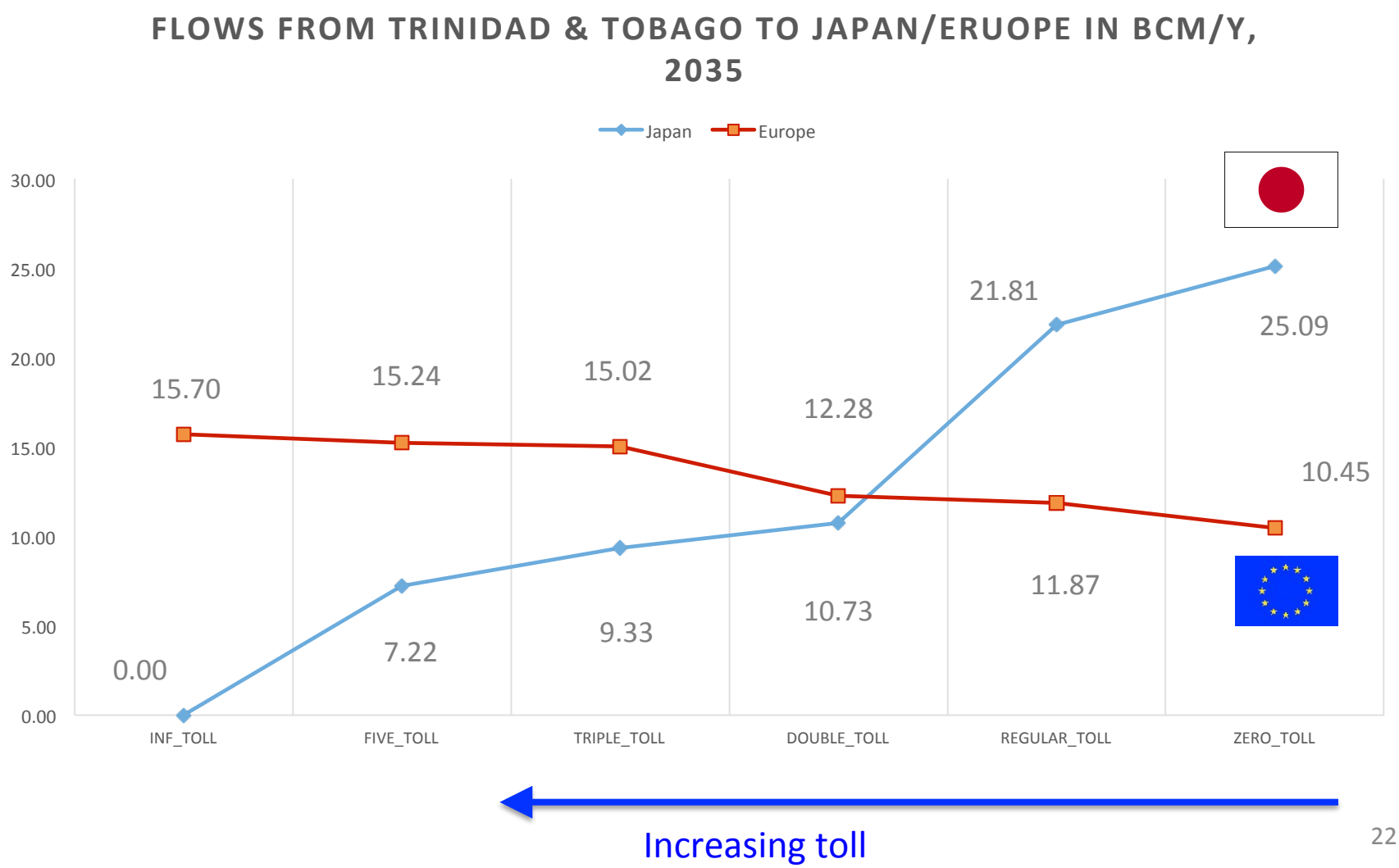
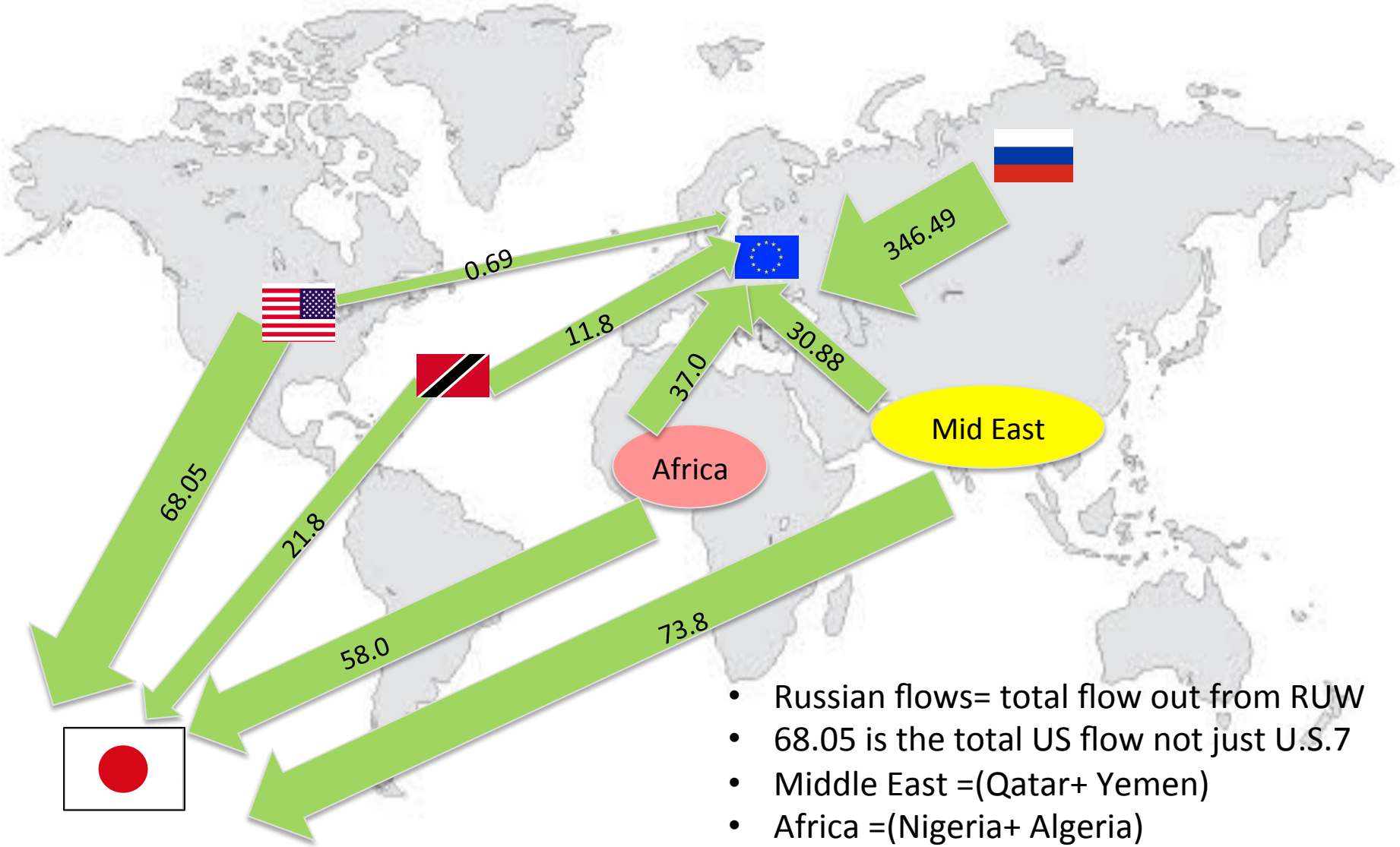
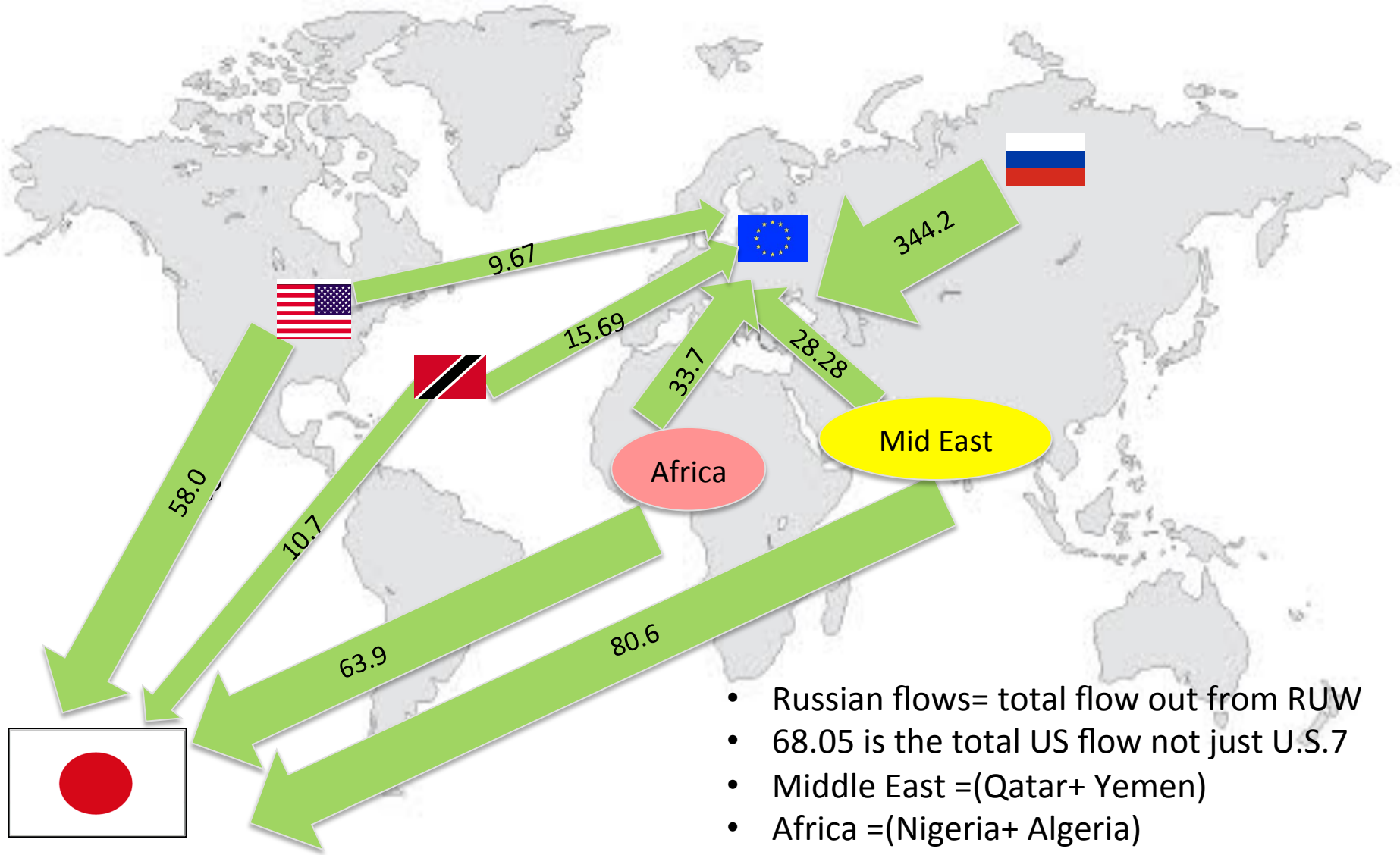


Dynamics of Flows: Regular Tariff Scenario, Flows in Bcm/y for 2035



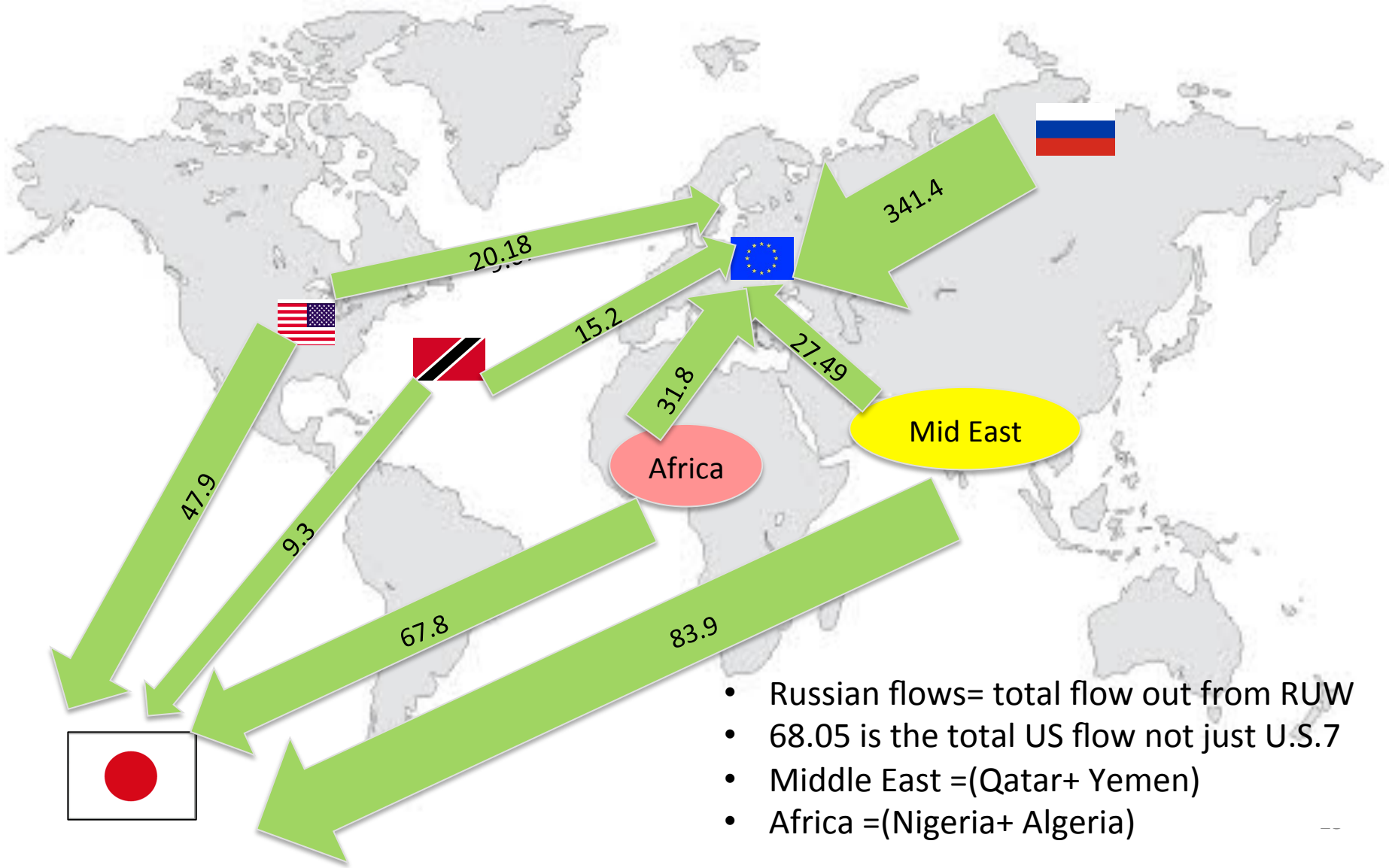
- Russian flows= total flow out from RUW
- 68.05 is the total US flow not just U.S.7
- Middle East =(Qatar+ Yemen)
- Africa =(Nigeria+ Algeria)

Dynamics of Flows: Double Tariff Scenario, Flows in Bcm/y for 2035



- Russian flows= total flow out from RUW
- 68.05 is the total US flow not just U.S.7
- Middle East =(Qatar+ Yemen)
- Africa =(Nigeria+ Algeria)

Dynamics of Flows: Triple Tariff Scenario, Flows in Bcm/y for 2035



- Russian flows= total flow out from RUW
- 68.05 is the total US flow not just U.S.7
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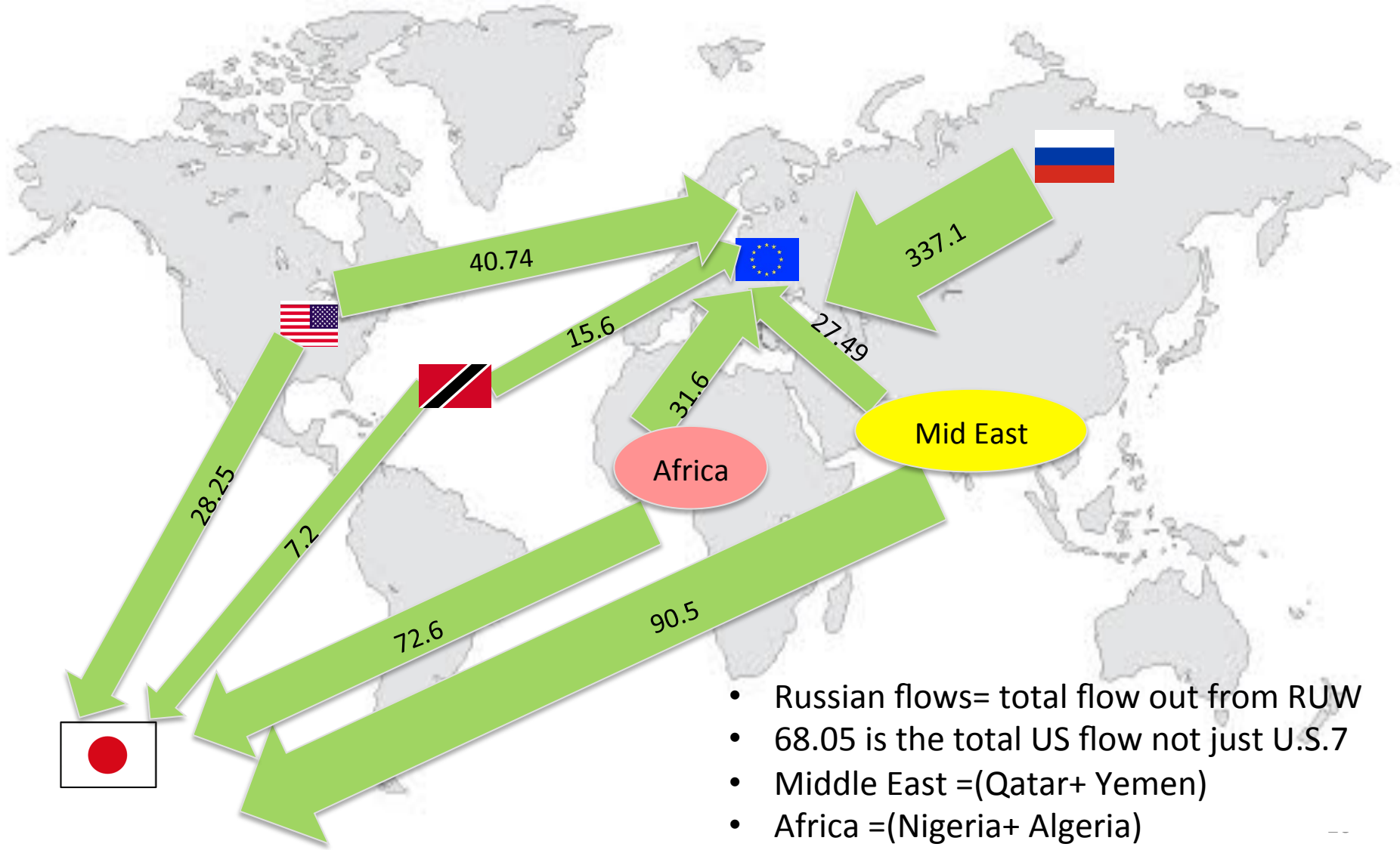
- Africa =(Nigeria+ Algeria)

Dynamics of Flows: Five-fold Tariff Scenario, Flows in Bcm/y for 2035



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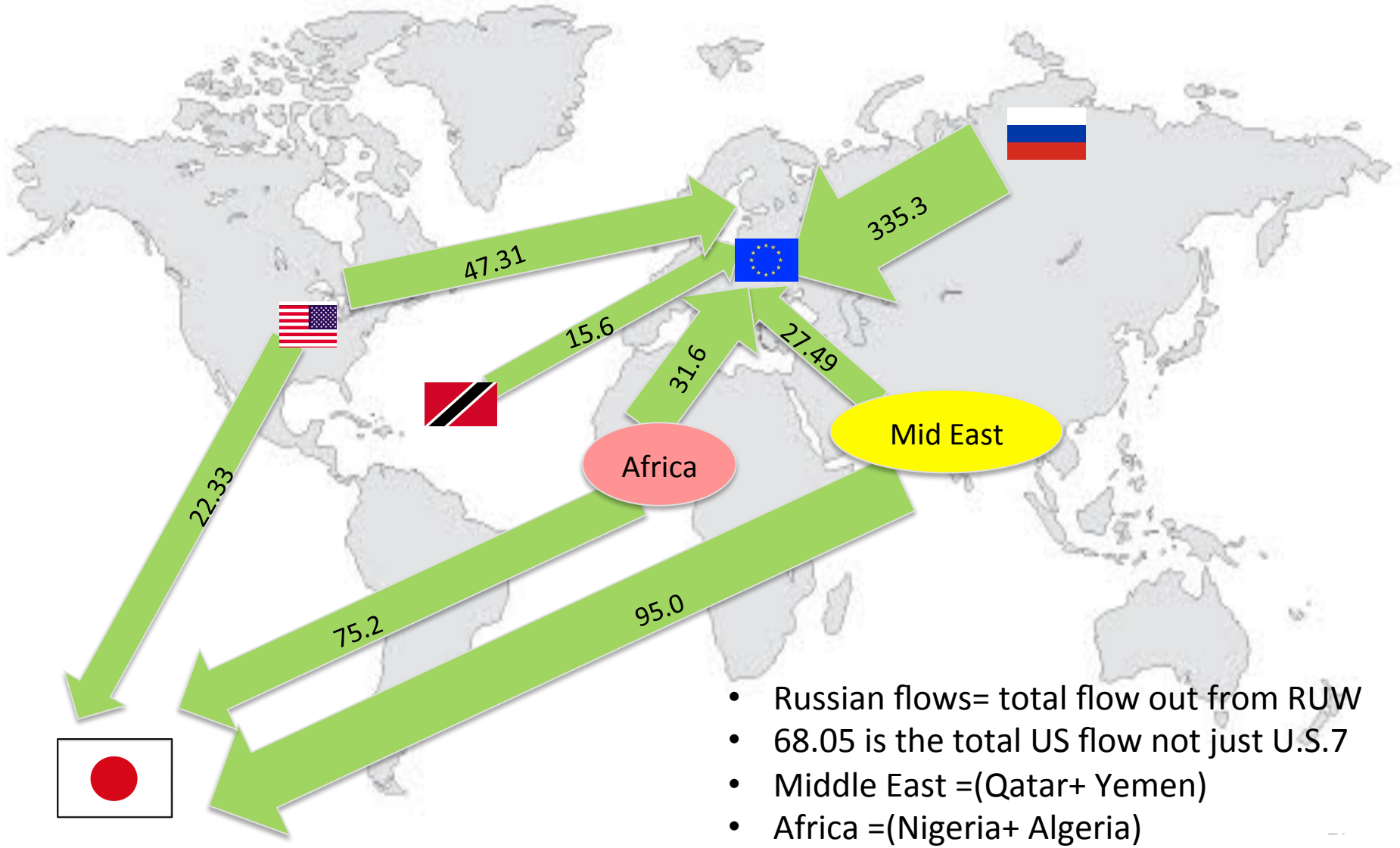
Dynamics of Flows: Infinite Tariff Scenario, Flows in Bcm/y for 2035



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Conclusions and Next Steps

- Nash-Cournot approach to large-scale energy security can provide useful results for modelers and policy decision-makers
- An increase in the Panama Canal tariff causes dynamic changes in flows between Europe and Asia for Trinidad and US, e.g.,
  - As the tariff increases, the flows from U.S. and Trinidad to Japan decrease, but the flows from these two countries to Europe go up
  - U.S. and Trinidad flows slightly displace flows from Middle East, African , and Asian suppliers to Japan node
  - When the canal is available, Qatar, Yemen, Algeria, Indonesia, and Nigeria will lose their market shares
  - Russian flows to Europe are affected by the direction of U.S. LNG Exports (2-3% change)
  - Russia does not utilize South Stream in any scenarios
- Panama Canal operator has some sort of market power (future work?), maybe some sort of Stackelberg leader-follower game, current chapter in Seksun Moryadee's thesis.?

References

1. Barton,B., Redgwell, C. and Ronne, A. and Zillman, D., 2004. *Energy Security: Managing Risk in a Dynamic Legal and Regulatory Environment*, Oxford University Press, Oxford, UK. ISBN 9780199271610.
2. EU,2000. "Towards a European strategy for the security of energy supply".
3. S.A. Gabriel, A.J. Conejo, J.D. Fuller, B.F. Hobbs, 2013. *Complementarity Modeling in Energy Markets*, Springer.
4. Martchamanol J. and Kumar S., 2012. "Thailand's energy supply indicators" *Renewable and Sustainable Energy Review* 16(2012) 6103-6122.
5. Moryadee, S. and Gabriel, S.A., 2014. "Panama Canal Expansion: Will the Panama Canal be a Game Changer for LNG Exports to Asia?", in review, September.
6. Moryadee, S., Gabriel, S.A., Avetisyan, H. 2013. "Investigating the Potential Effects of U.S. LNG Exports on Global Natural Gas Markets, accepted, *Energy Strategy Reviews*.
7. Moryadee, S., Gabriel, S.A., Rehulka, F. 2014. "The Effects of Panama Canal Tariffs on LNG Marketed", accepted, *Journal of Natural Gas Science & Engineering*, June.
8. Sovacool, B.,2011. *The Routledge Handbook of Energy Security*, Taylor and Francis, New York.