

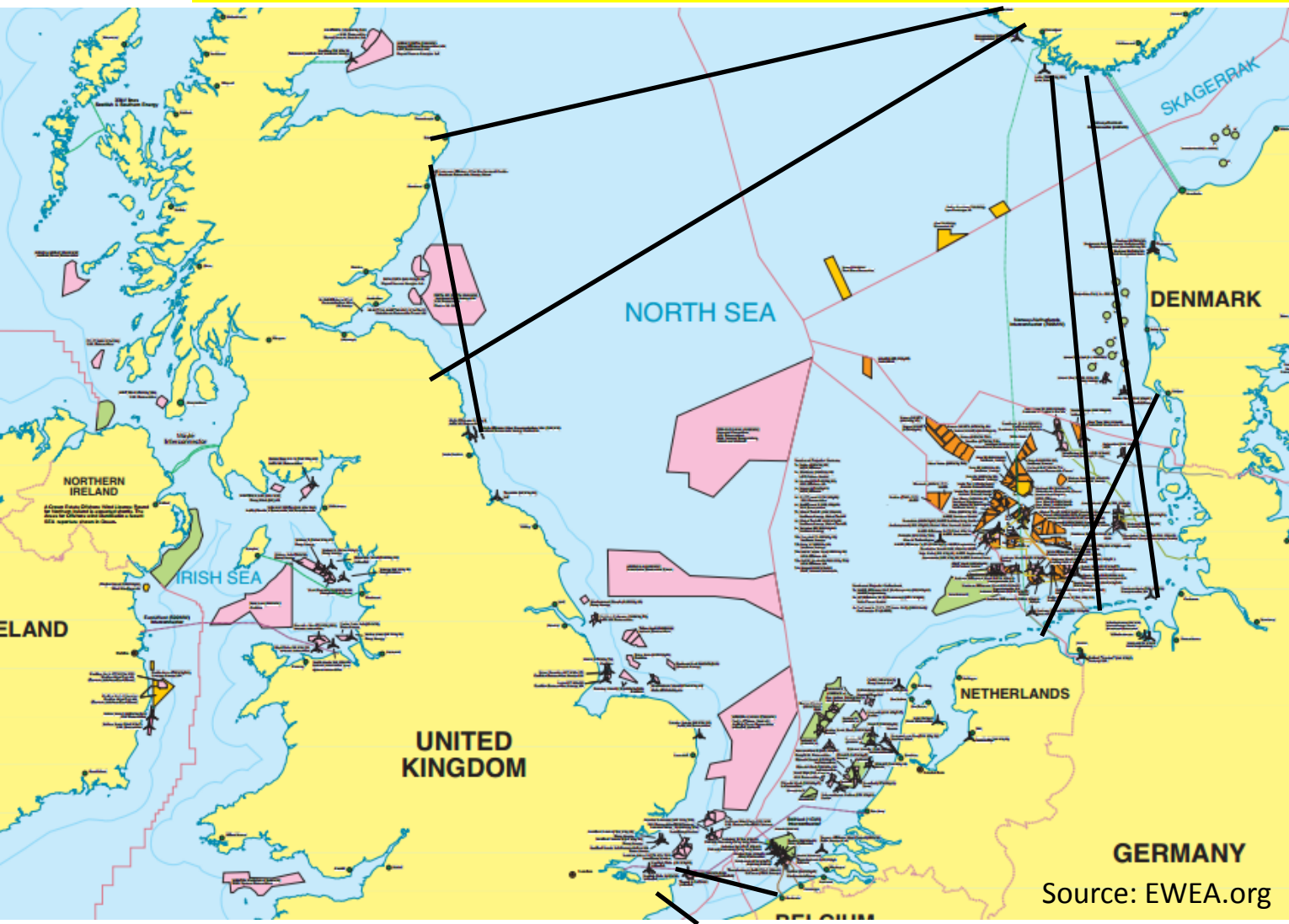
Interconnecting North Sea Wind Power Plants

Josco Kester (ECN Wind Energy)

Wind Integration Workshop 2014
Berlin, 12-11-2014

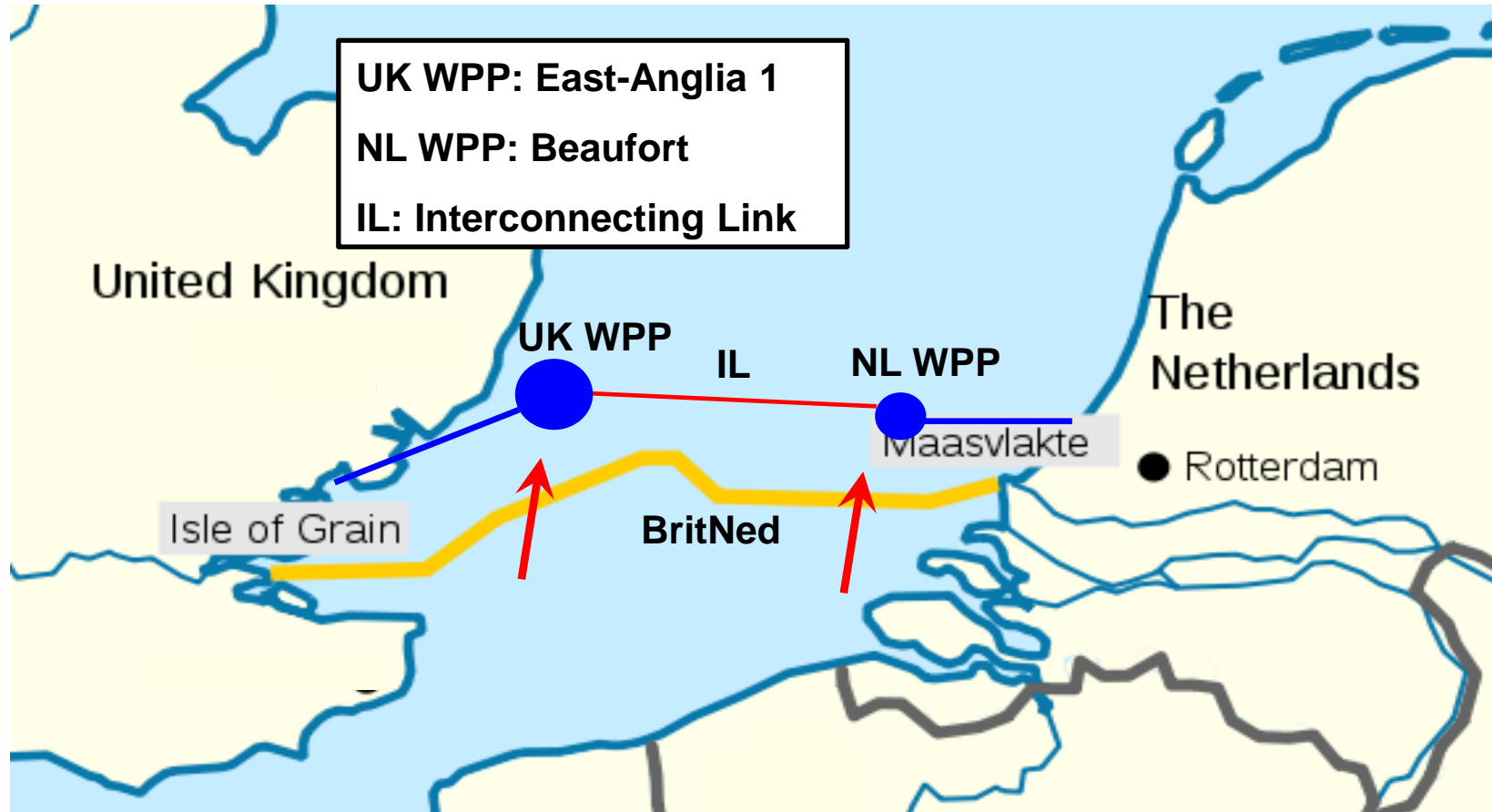
WPP export cables and interconnectors: ECN

Why not combine?



- Lower investments
- Higher reliability
- Less land use
- Dual income
- Hedging risks
- Integrated offshore grid

Case study for a UK and NL WPP: Is an Interconnecting Link feasible?



Part of VATTENFALL



Perspectives

1. Technical feasibility
2. Stakeholder interests
 - Interconnecting Link investor
 - WPP developer
 - TSO
 - Government **-- WORK IN PROGRESS --**
3. Legal feasibility

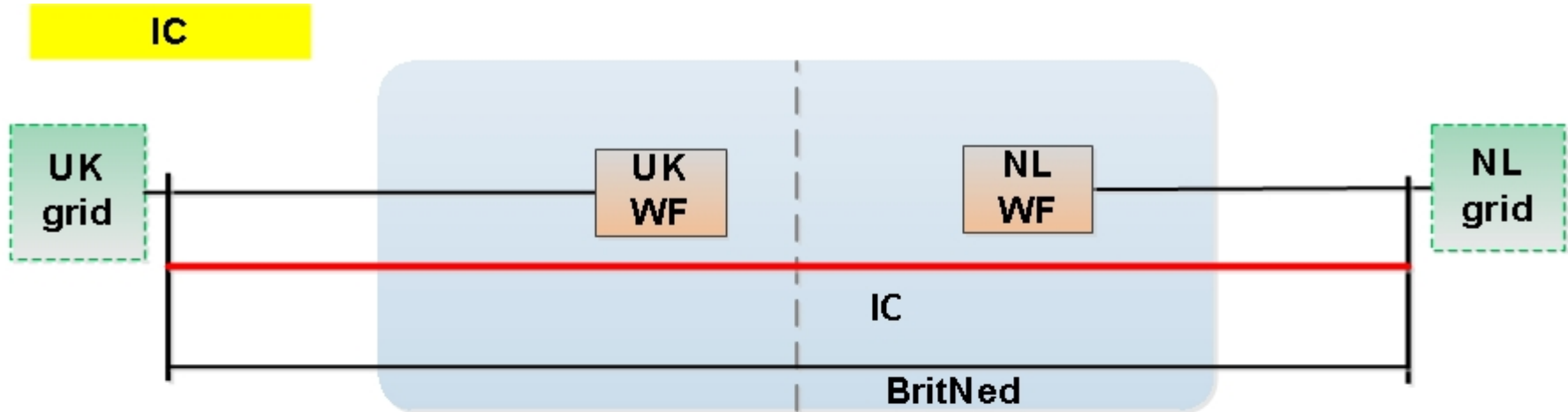
Conclusions

- Technology
 - Combining Interconnectors and Export Cables is technically feasible
 - Experience with control and protection of Multi-Terminal DC grids is needed
- Economics
 - Marginal decrease LCoE of offshore wind energy in our scenarios: ≤ 3 €/MWh (3%)
 - Depends strongly on IL hurdle rate, WPP size, location and market price difference
 - Uncertainties of costs and benefits are large
 - Higher risk perception because of complexity in design and operation
- Legal
 - Legal framework is insufficient for IL permitting and operation
- Perspective is decisive
 - Stakeholders have opposing interests → different preferred scenarios

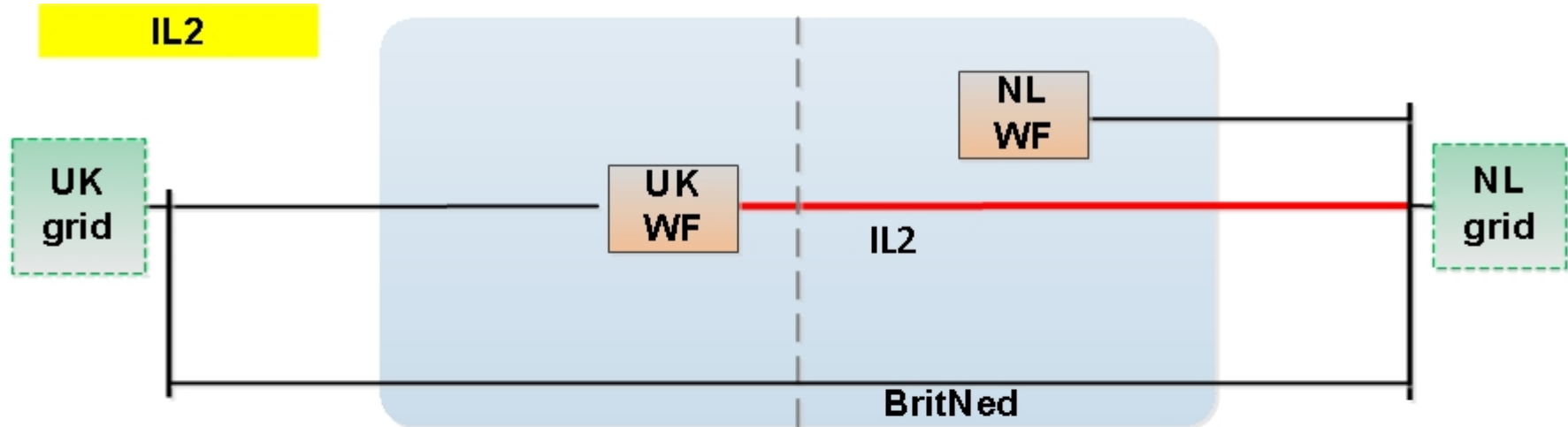
Recommendations

- Interconnecting Links are interesting:
 - If costs and risks of offshore DC technology are significantly lower
 - For large WPPs, far offshore, close to interconnector with high congestion rent
 - As a means to pre-finance export links for future WPPs
- Policy measures needed
 - Clear legal definition of Interconnecting Link and its operation
 - International coordination of renewable incentive and permitting schemes
 - Compensation mechanism for stakeholders that are negatively affected

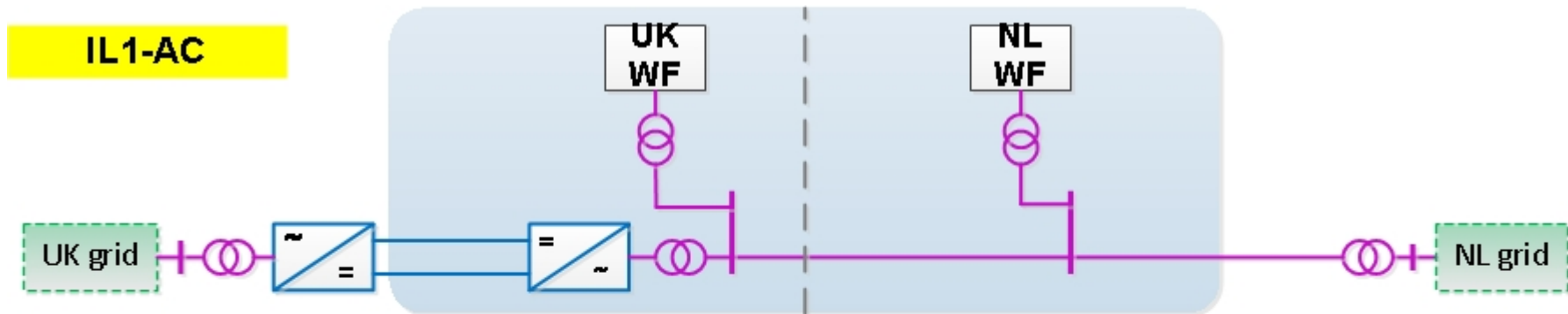
Scenario definition: Topologies



Scenario definition: Alternative topologies



Scenario definition: Technical implementations



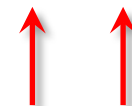
Stakeholder interests

- Interconnecting Link investor
 - IRR
- WPP developer
 - Availability
- TSO
 - Market Integration
- Government
 - Social welfare
 - Land use
 - LCoE reduction

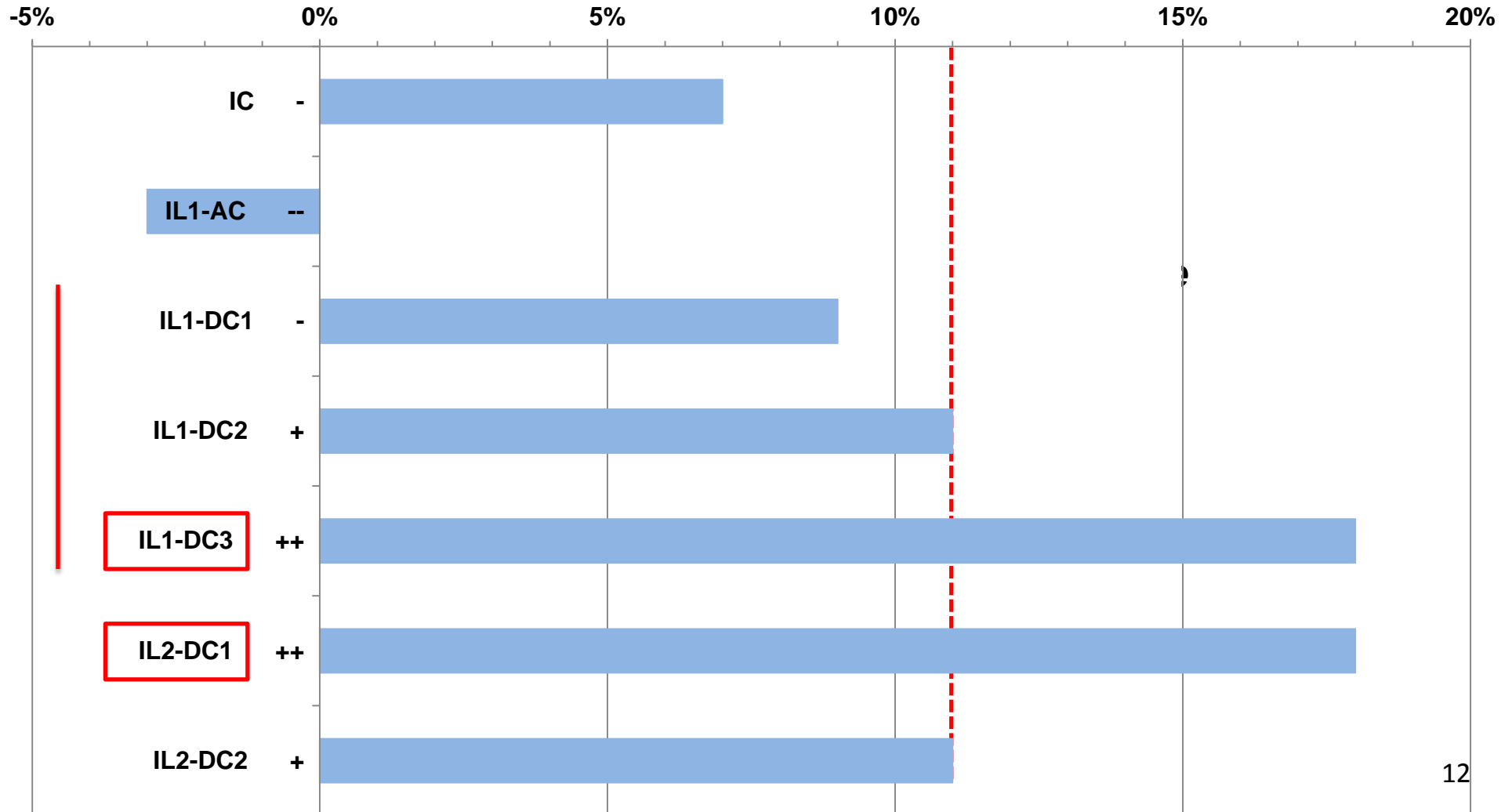
Note: Costs for onshore grid reinforcements are neglected

Stakeholder interests

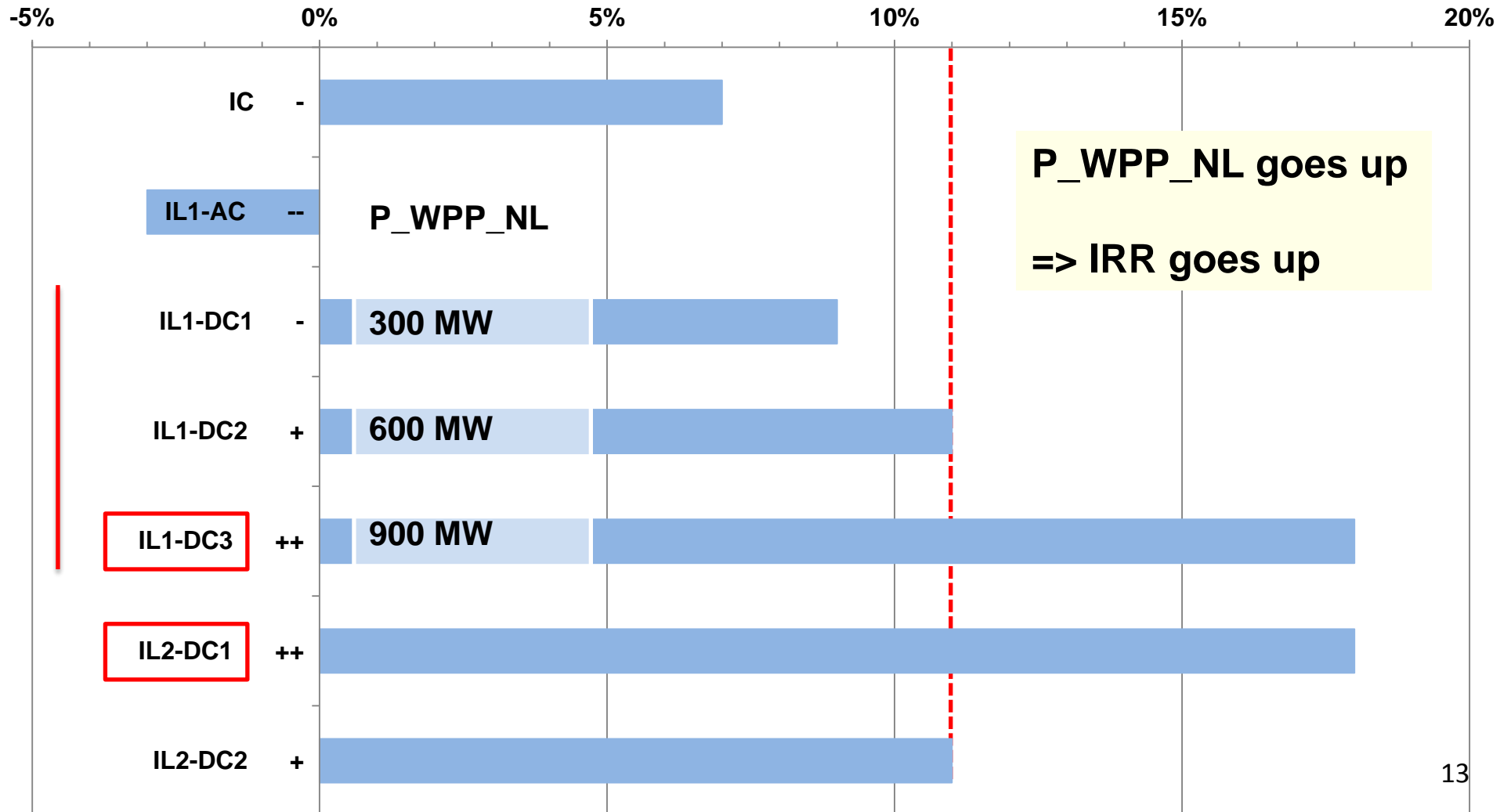
		300 MW							1200 MW						
		IC	T1-AC	T2-AC	T3-AC	T1-DC	T2-DC	T3-DC	IC	T1-AC	T1-DC1	T1-DC2	T1-DC3	T2-DC1	T2-DC2
IL investor	IRR \geq 10.9%	--	--	--	--	--	--	--	-	--	-	+	++	++	+
UK WPP	Availability	0	0	+	++	+	+	0	0	++	++	++	++	++	++
NL WPP	Availability	0	+	0	+	-	0	+	0	+	-	-	-	0	0
TSOs	Market Integration	+	0	+	0	0	+	0	++	+	+	+	+	+	+
GOVs	Social benefits EU	?	+	-	--	-	-	-	-	--	--	--	++	--	+
GOVs	Social benefits UK	?	++	++	--	++	++	-	++	--	--	--	--	--	++
GOVs	Social benefits NL	?	-	-	-	--	-	-	+	--	--	++	++	--	--
GOVs	Land use	-	+	+	+	+	+	+	-	+	+	+	+	+	+
GOVs	Δ LCOE UK														
GOVs	Δ LCOE NL														
	OVERALL SCORE														



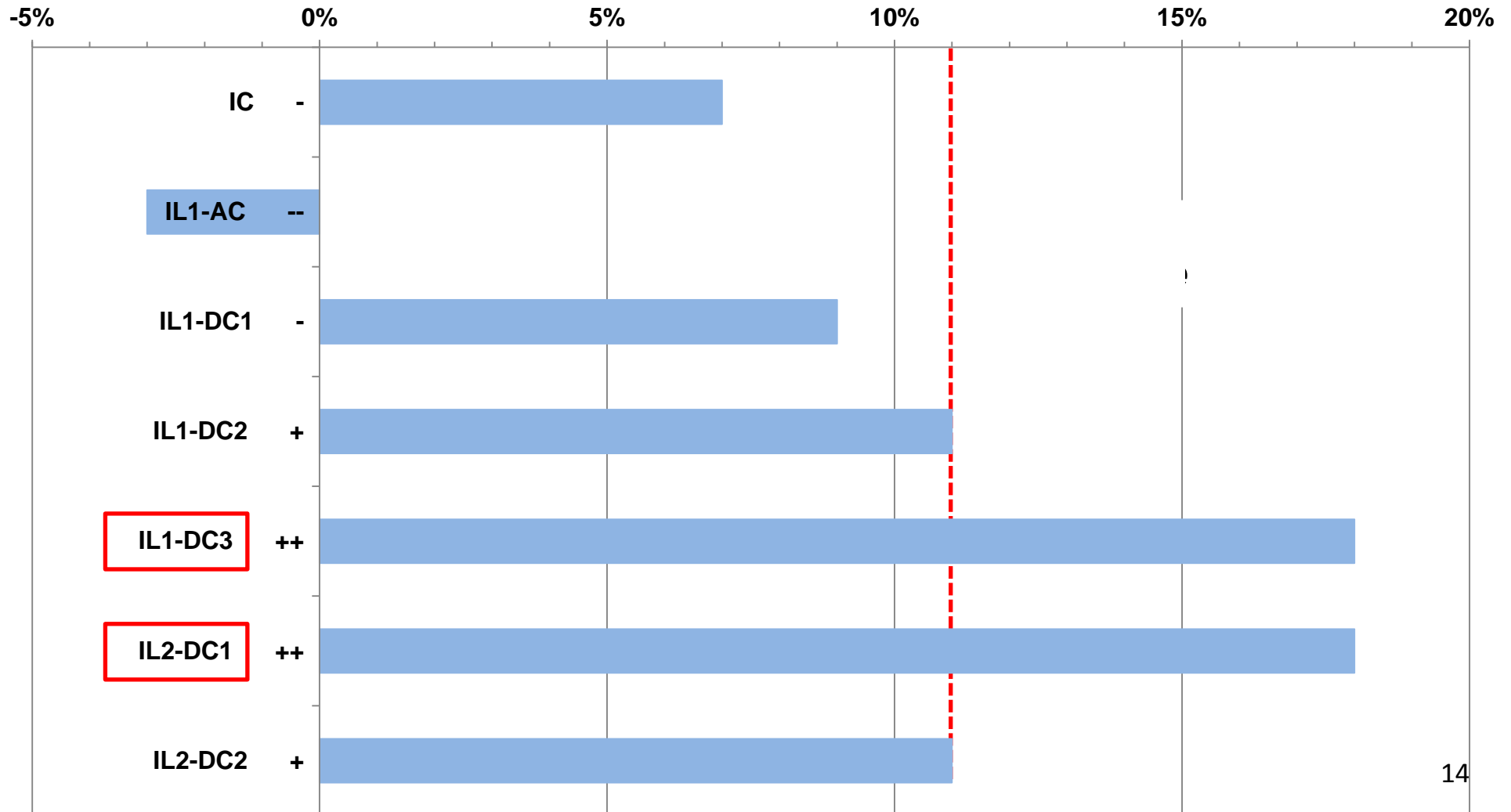
Interconnecting Link investor: IRR



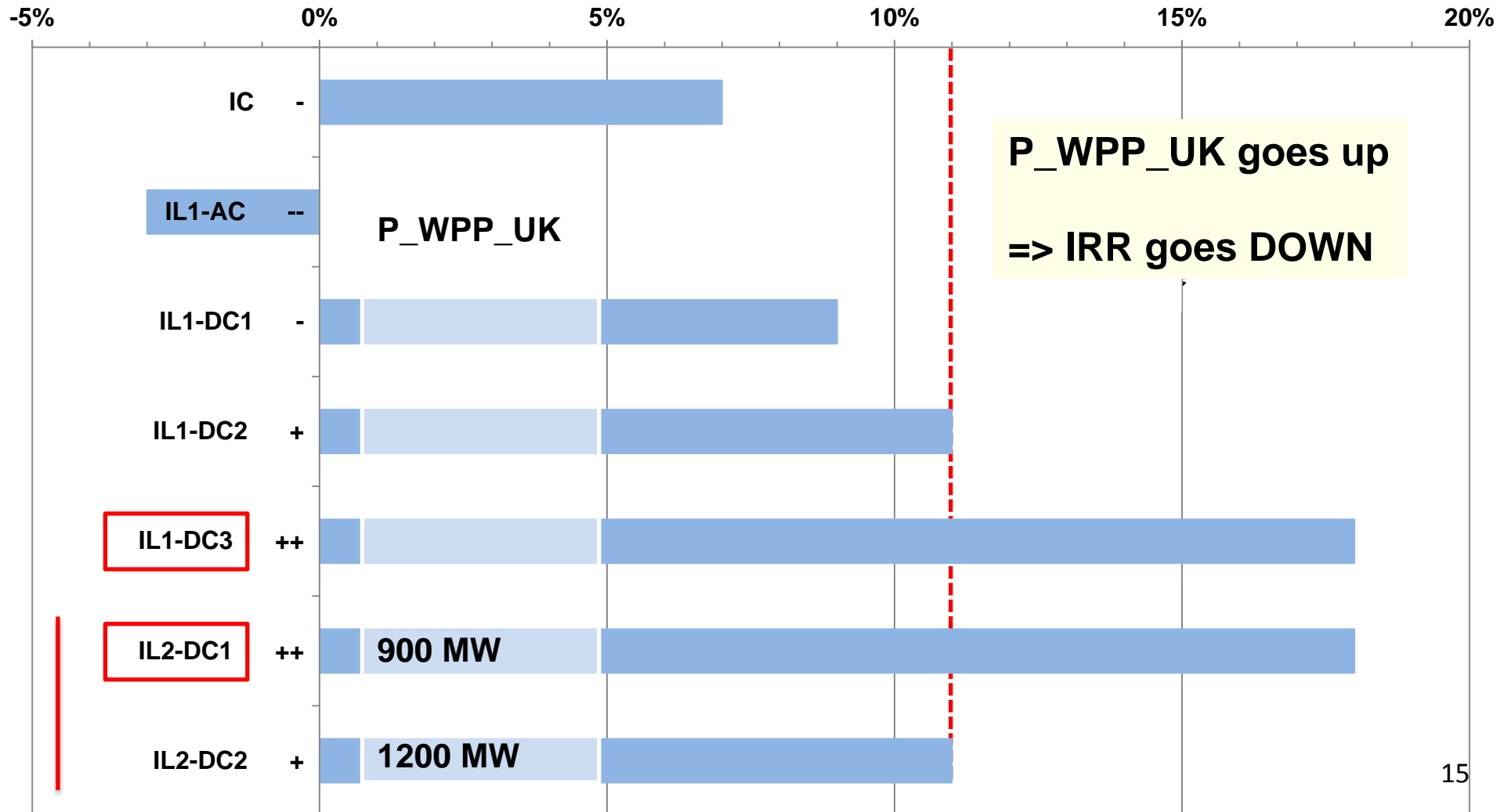
Interconnecting Link investor: IRR



Interconnecting Link investor: IRR

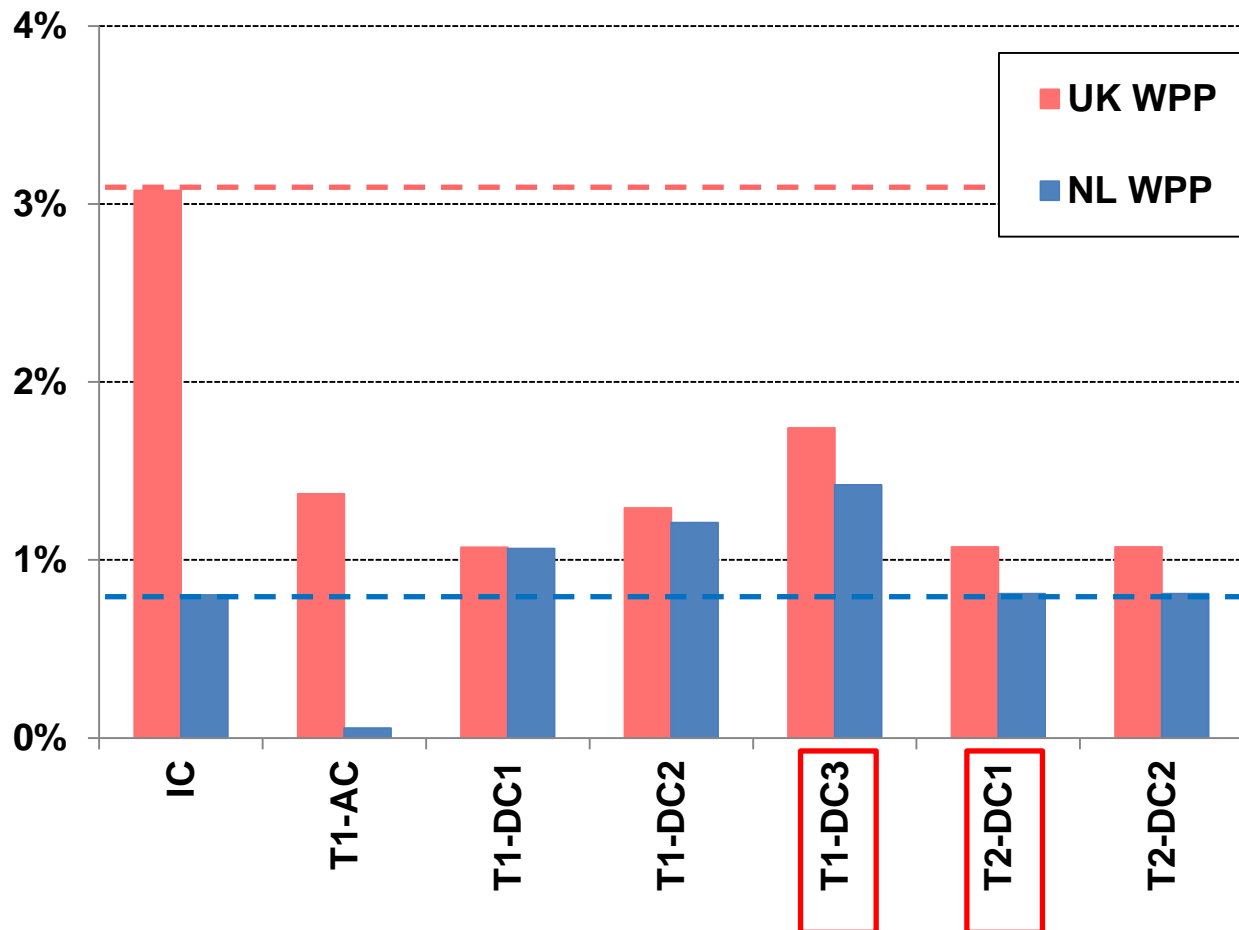


Interconnecting Link investor: IRR



WPP developer: Unavailability

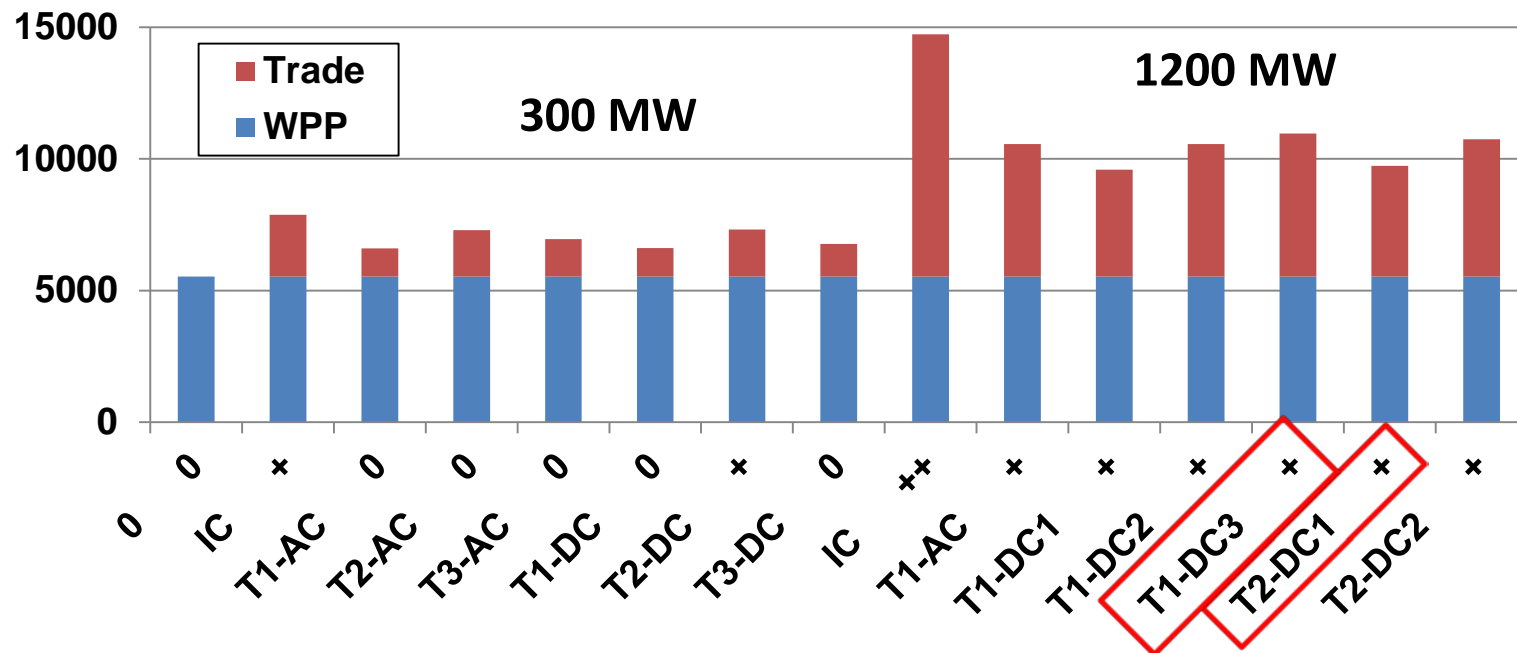
Energy not delivered



- Unavailability UK WPP >> unavailability NL WPP
- Unavailability UK WPP decreases by $\geq 45\%$
- Unavailability NL WPP decreases by 90%:
T1-AC link
(very expensive)
- Unavailability NL WPP *increases* for T1-DC links

TSO: Market Integration

Power transport between offshore grid and onshore grids (GWh/yr)

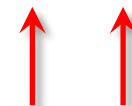


Best option: 1200 MW IC ($E_{\text{trade}} = 9200$ GWh/yr)

Second best: 1200 MW ILs ($E_{\text{trade}} = 4000-5200$ GWh/yr)

Stakeholder interests

		300 MW							1200 MW						
		IC	T1-AC	T2-AC	T3-AC	T1-DC	T2-DC	T3-DC	IC	T1-AC	T1-DC1	T1-DC2	T1-DC3	T2-DC1	T2-DC2
IL investor	IRR \geq 10.9%	--	--	--	--	--	--	--	-	--	-	+	++	++	+
UK WPP	Availability	0	0	+	++	+	+	0	0	++	++	++	++	++	++
NL WPP	Availability	0	+	0	+	-	0	+	0	+	-	-	-	0	0
TSOs	Market Integration	+	0	+	0	0	+	0	++	+	+	+	+	+	+
GOVs	Social benefits EU	?	+	-	--	-	-	-	-	--	--	--	++	--	+
GOVs	Social benefits UK	?	++	++	--	++	++	-	++	--	--	--	--	--	++
GOVs	Social benefits NL	?	-	-	-	--	-	-	+	--	--	++	++	--	--
GOVs	Land use	-	+	+	+	+	+	+	-	+	+	+	+	+	+
GOVs	Δ LCOE UK														
GOVs	Δ LCOE NL														
	OVERALL SCORE														



Government interest: Land Use

Source: premierconstructionnews.com



Interconnecting Link needs no space for onshore stations and cables

- Saves scarce space in cities
- Saves nature

Government interest: LCoE reduction

Scenario	WPP_NL Δ LCOE [€/MWh]	
	T1_DC3	T2_DC1
Unavailability	+0.54	0
NPV surplus IL	-0.58	-1.6
Total Δ LCOE	-0.04	-1.6
Total Δ LCOE (relative)	0%	-2%

Scenario	WPP_UK Δ LCOE [€/MWh]	
	T1_DC3	T2_DC1
Unavailability	-1.1	-1.6
NPV surplus IL	-0.58	-1.6
Total Δ LCOE	-1.7	-3.2
Total Δ LCOE (relative)	-1%	-3%

- Marginal LCoE reduction in our scenarios
 - up to 3%
- Depends heavily on many variables
 - Costs, WPP location, WPP size, IRR hurdle, market price differences

Legal feasibility

- Construction of an Interconnecting Link by a private party or TSO possible
- Operation not supported by existing regulations
- Issues to be solved include:
 - What is the legal status of Interconnecting Link?
 - Who is allowed to operate it?
 - Mandatory capacity auctioning of the interconnector capacity?
 - If so, how can priority access for the connected WPPs be guaranteed?
- Other regulatory obstacles:
 - National character of incentive programs and permit procedures for RES generation
 - Cost recovery of pre-financing
- Solutions have been suggested to solve these legal issues

Recommendations

- Interconnecting Links could be interesting:
 - If costs and risks of offshore DC technology are significantly lower
 - For large WPPs, far offshore, close to interconnector with high congestion rent
 - As a means to pre-finance export links for future WPPs
- Policy measures
 - Clear legal definition of Interconnecting Link and its operation
 - International coordination of renewable incentive and permitting schemes
 - Compensation mechanism for stakeholders that are negatively affected