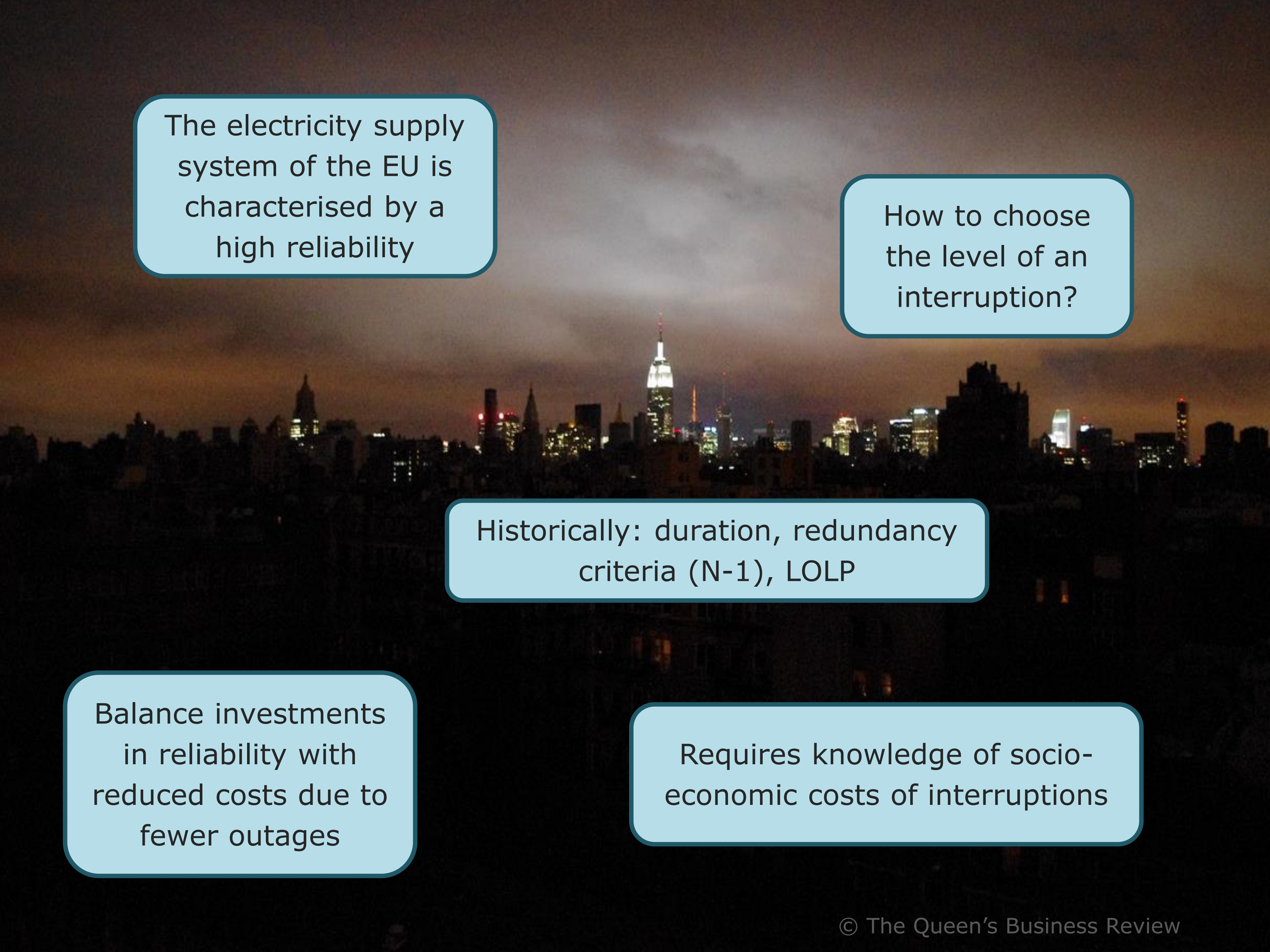

The electricity supply system of the EU is characterised by a high reliability
How to choose the level of an interruption?
Historically: duration, redundancy criteria (N-1), LOLP
Balance investments in reliability with reduced costs due to fewer outages
Requires knowledge of socio-economic costs of interruptions

Estimating the socio-economic costs of electricity supply interruptions

Abhishek Shivakumar, Manuel Welsch, Constantinos Taliotis,
Tomislav Baričević, Dražen Jakšić, Mark Howells,

IEW 2015
3-5 June, Abu Dhabi

Focus

- **Objective: to spur discussions** on interruptions and their costs
- **Social dimension:** not only industries, also citizens
- **Costs:** direct vs. indirect, how to share them between stakeholders
- **Case studies:** to showcase the different types of interruptions
- **Evolution:** impact of increased shares of renewables
- **Beyond kWh:** services rather than electricity
- **Modelling approaches & databases:** minor focus
- **International cases:** putting the EU in context

Characterising Interruptions

Types of end-users: hospital vs. industrial plant vs. household

Time of occurrence: weekday vs. weekend, winter vs. summer

Duration: instant losses (PC files) vs. time-dependent losses (food)

Advance notification: e.g., elevator; regular outages: notifications not as important any longer -> lower immediate cost, but less confidence in system

Perceived reliability level: vulnerability conflict -> higher perceived reliability leads to higher vulnerability in case of outage

Source of the outage: failure in network vs. failure in power plant

Composition of Costs

- *Consumers have no choice to choose tariff depending on reliability*
- *No market mechansm to derive the value of the cost of interruption*
- *Utilities/TSOs lack balanced incentives to engage in investments*

Direct:	Infrastructure
Indirect:	Production outage
Macro-economic long-term:	Change in investments, e.g., choice of business location

Households

Only partly material -> costs such as fear, inconvenience, loss of leisure time

-> Willingness-to-Pay (WTP)

Industry/Commerce

1. Output
2. Loss of productivity
3. Damage
4. Labour
5. (Loss in reputation)

Quantifying the Costs

Surveys/Interviews

- Willingness to Pay (WTP)
- Willingness to Accept (WTA)
- Choice experiment
- e.g., winter, WTP is 1/3 higher in Austria

Production-function

- Estimates welfare costs accross different sectors, durations, times
- e.g., lost production, reduced convenience
- Uses statistical information

Market behaviour

- Revealed preferences/expenditures
- e.g., backup facilities, insurances, interruptible contracts
- US: 170 GW of backup generators

Case studies

- List and monetise effects of outage
- Surveys after interruption

Case Study - Cyprus: Isolated & vulnerable

- 11 July 2011: 98 containers of ammunitions exploded at naval base
- 650 MW power plant damaged
- >50% of total capacity of Cyprus
- No interconnections -> rolling blackouts
- Temporary units installed
- Price increase of 36% for consumers
- Restoration: €220 million, finished in 2013

Households*		
2011 1st half	**2011 2nd half**	**2012 1st half**
€/kWh		
0.205	0.241	0.278

Vasilikos power plant

Case Study - Italy: Timing Matters

- 3 AM, 28 September 2003: 2 transmission lines from Switzerland to Italy were cut off due to storm
- Almost all of Italy without power for 12 hours
- Nuit Blanche in Rome: annual overnight festivities -> hundreds of people trapped in underground trains
- 110 trains cancelled
- 30,000 people stranded on trains accross Italy
- Heavy rain: many people sleeping in train stations and on the streets

Rome during Outage
© Reuters/Alessia Pierdomenico

Integrating Renewables (RE) through Smart Grids (SG)

Distributed RE + Storage

- Same reliability level possible
- E.g., small hydro: black-start capable
- Germany: loans/subsidies for PV storage
- Distribution of costs for grid access requires consideration

Smart Grids

- Increasing RE -> SG
- Self healing, able to contain outage and minimise its duration and cost
- New sources of flexibility (demand-side)

Demand-side management

- SGs: minimise outage cost through prioritising loads (hospitals /industry)
- Not necessarily limited to consumer groups, but also within one group
- 50% of household demand not instantly required

Regulation

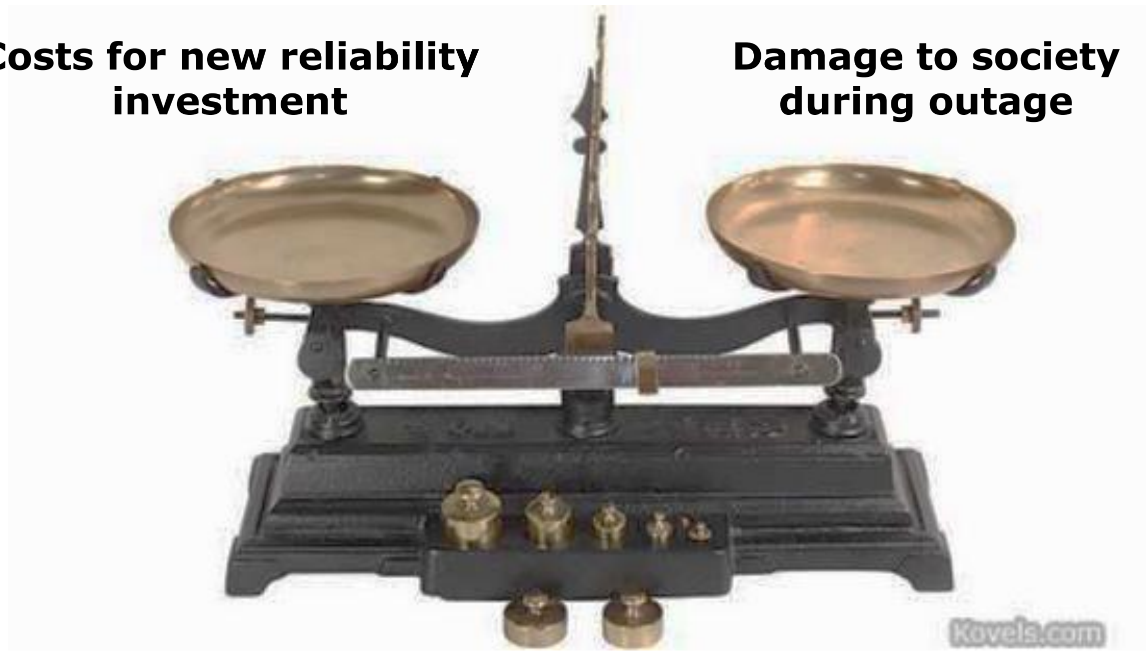
- Currently mostly primary assets rewarded, not performance based
- Few of the EU28 have created strong regulatory support for demand response

Looking Forward

Calculating the economically optimal interruption levels

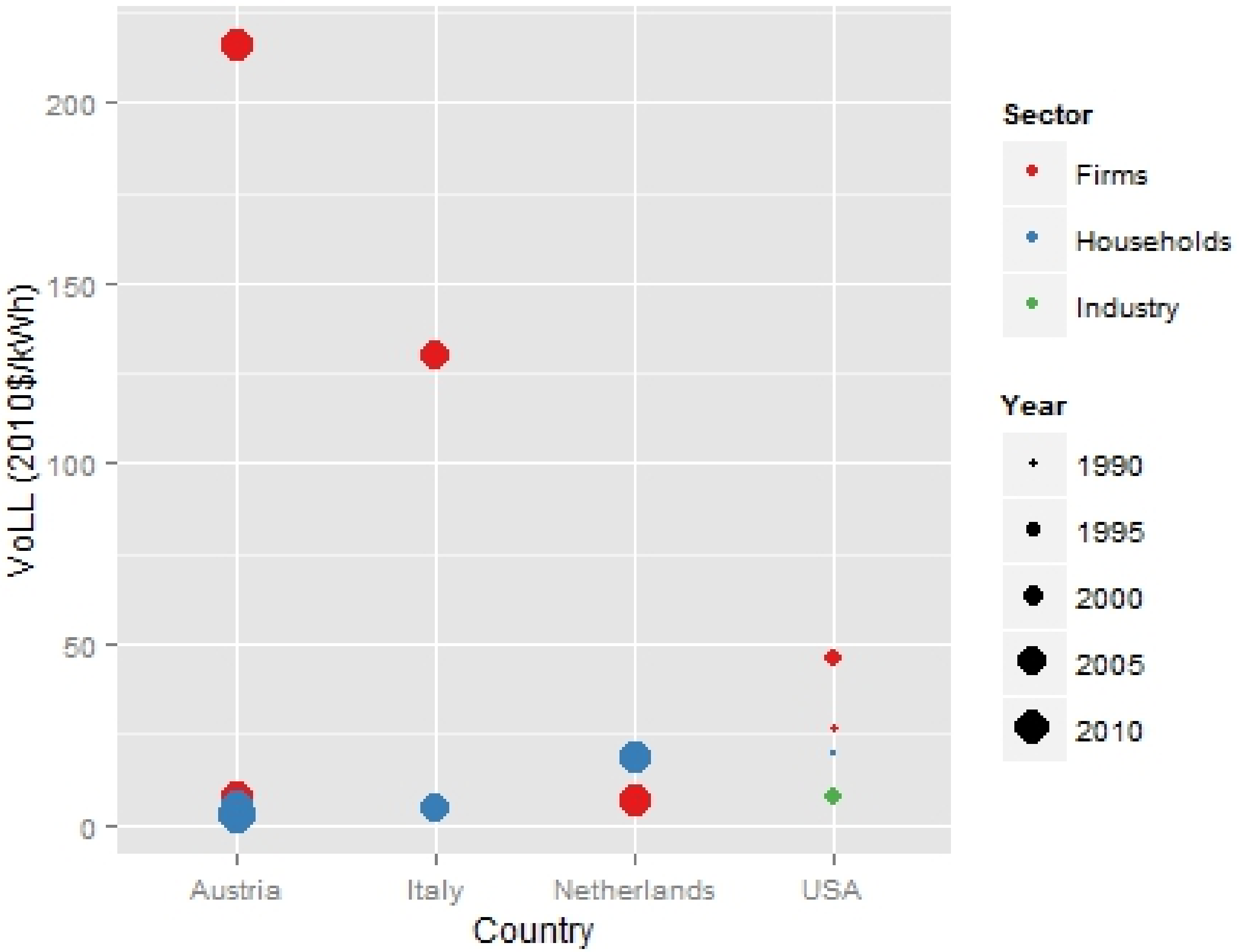
Costs for new reliability investment

Damage to society during outage



- Required to know the value society places on supply security
- Dependent on time, duration, service
- Initial estimate may be less arbitrary then, e.g., Loss of Load Propability (LOLP)

Need for a consistent approach



International context: examples from Sub-Saharan Africa

Indicator	Senegal	Nigeria	Sub-Saharan Africa	World
Number of electrical outages in a typical month	25.8	26.3	10.7	8.6
Duration of a typical electrical outage (hours)	2.3	8.2	6.6	4.0
Losses due to electrical outages (% of annual sales)	5.1	8.9	6.7	4.8
Percent of firms owning or sharing a generator	90.7	85.7	43.6	31.6
Proportion of electricity from a generator (%)	30.8	47.5	13.8	7.1
Percent of firms identifying electricity as a major constraint	57.5	75.9	50.3	39.2

Looking Forward

Modelling Tools

Modified version of tools like APOSTEL, OSeMOSYS or PLEXOS can optimise extent of interruptions by minimising socio-economic costs

Proposed Vision / Next Steps

- Consistent investigation of VoLL across EU-28
- Standardised database for aggregating costs

Thank you for your attention

For further information please contact

Abhishek Shivakumar
ashi@kth.se

Dr. Manuel Welsch
manuel.welsch@energy.kth.se

KTH VETENSKAP OCH KONST
ROYAL INSTITUTE OF TECHNOLOGY

Division of dESA Energy Systems Analysis