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Investment risk in the energy sector on the example of a biogas power plant

Directed Technical Change, Capital Intensity Increase and Energy Transition: Evidence from China

Dong Wang, Amin Mugera,** and Ben White****

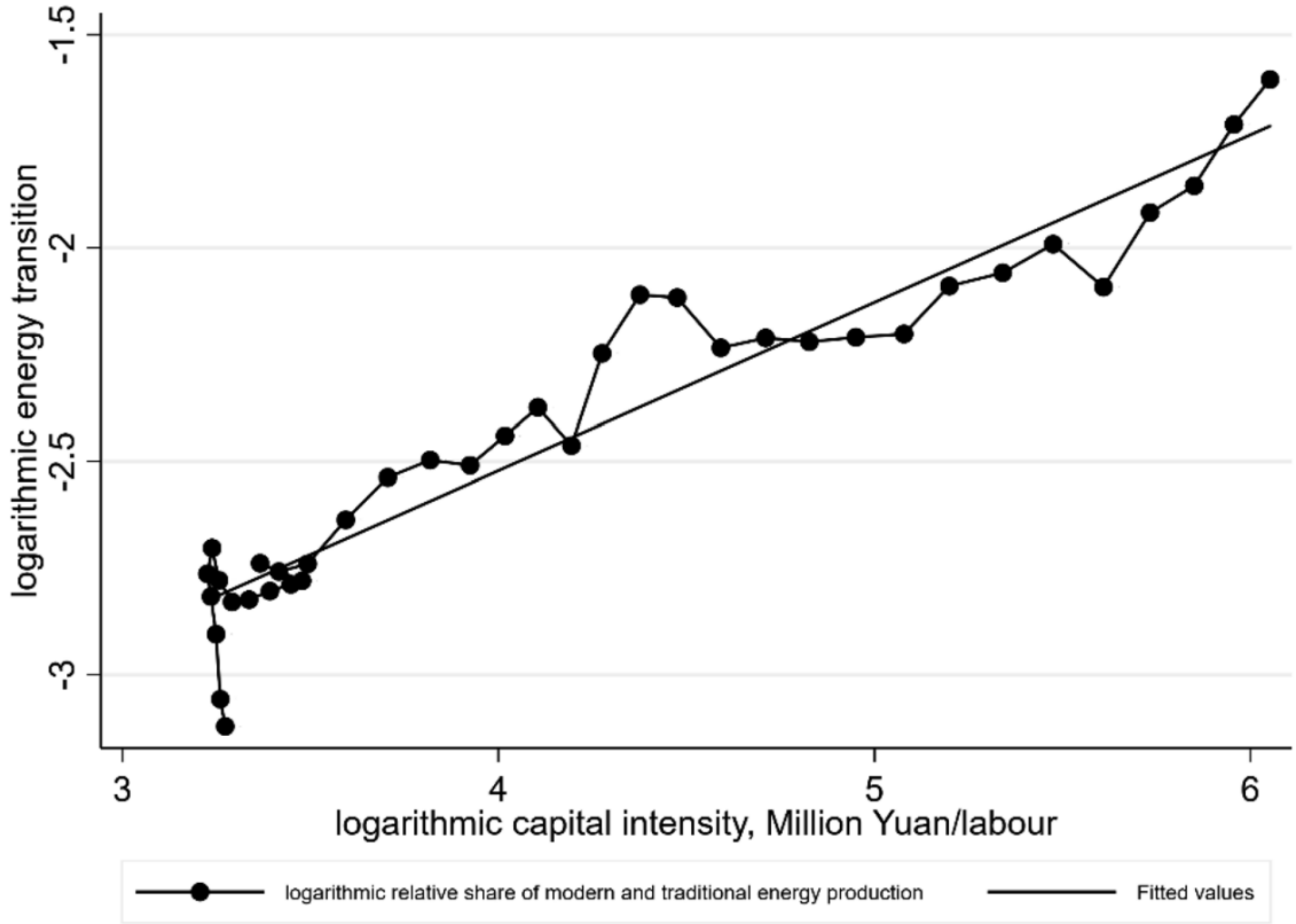
ABSTRACT

This paper analyses the causes of China's energy transition since 1978 when the economic reform policy was launched. We aim to determine if increasing capital intensity in the Chinese economy is driving a shift in the energy mix towards modern energy sources, such as solar electricity. The empirical investigation is based on national level time series data from 1978 to 2015. The results of a Granger Causality test show that increasing capital intensity causes transition to modern energy in the long run, but not *vice versa*. The impulse-response analysis, based on the Johanson cointegration and vector error correction model (VECM), verifies that capital intensity determines energy transition in the long-run and the adjustment period to an exogenous shock from capital intensity is around five years. This is in line with China's National Five-year Plans which often introduce major shifts in energy and industrial policy. We conclude China's energy transition is driven by capital deepening and biased technical change towards capital-intensive modern energy in the long run. The rate of change is increased by exogenous investment shocks partly as a result of policy initiatives introduced by China's Five Year Plans.

Keywords: Energy transition, Capital intensity, VECM; Granger test

https://doi.org/10.5547/01956574.40.SI1.dwan

Figure 4: Energy transition and capital intensity



Risk is related to/contains <u>uncertainty</u>

The energy sector is <u>dynamic</u>

- High capital intensity
- Big impact on the (entire) economy

An fresh view at energy transition

- Shifting from an op-ex (operating expenditure) heavy system to a cap-ex (capital expenditure) heavy system
- Like the difference between buying and renting a movie

The old way (**op-ex**)

- Renting a movie ~ like a coal power plant
  - It’s cheap to start (you don't need much money right now), but you have to keep spending money forever to keep watching
  - The analogy: You build the plant, but you have to keep buying and burning coal every single day to make electricity

The new way (**cap-ex**)

- You save up all your allowance and buy the movie for €20
- It costs a lot of money right at the beginning (capital expenditure), but once you own it, watching it is basically free
  - You don't have to pay €2 every time anymore
- The analogy: In the energy world, this is like a solar farm
  - You have to spend a huge pile of money at the start to buy the panels and build the farm
  - Once it’s finished, the sun provides the fuel for free

- So, energy transition is just the world moving from the €2-every-time way to the buy-it-up-front way
- What’s the tricky part?
  - Because it costs so much money to start, people get nervous about “buying the movie” if they aren’t 100% sure it's the right one
    - That nervousness is what we call **risk**
      - If they feel risky (risk prone), they might decide it’s safer to just keep paying €2 every day, even if it costs more in the long run

How is capital intensity related to risk?

- The energy transition is like moving from buying a small snack every day to buying a whole kitchen
  - Uncertainty directly impacts the valuation and feasibility of capital-intensive projects

(1) **Technology risk and obsolescence**

In a rapidly evolving sector, there is a significant risk that a massive upfront investment in current technology (e.g. new solar panel types of superior efficiency) will be superseded by a better, lower-cost breakthrough before the original asset has paid for itself

This creates a wait-and-see approach that can delay the deployment of existing solutions

(2) **Regulatory and policy risk**

Because energy transition is often driven by government mandates, subsidies, or carbon pricing, the stability of the legal framework is paramount

If investors fear a policy reversal, where a change in administration or law removes financial incentives or changes grid access rules, they will demand a higher risk premium

This will make the project significantly more expensive to fund

(3) **Cost of capital and risk premiums**

This is borrowing fee: In finance, this is often expressed through the Weighted Average Cost of Capital (WACC)

- When a project is perceived as risky, **lenders** (e.g. a bank giving you a loan) and **equity investors** (e.g. a partner who buys a piece of your business, because they want to own a slice of the pie) require a higher rate of return to compensate for that risk
- In a capital-intensive environment, a high WACC can make a renewable project unviable, even if the actual technology is highly efficient
  - This is because the interest payments on the massive upfront debt become too burdensome

Lenders vs equity investors

- Equity Investors are often the risk-takers who put up the initial money to start a new, unproven green technology project
- Lenders usually step in once a project looks stable to provide the massive amounts of cheap debt needed to actually build it

If these two groups feel risk, the lender will charge a higher borrowing fee (interest), and the equity investor will demand a bigger slice of the pie (return)

- This makes the whole project more expensive to build

Paper examines the investment risk in the energy sector

Two important methods are used:

- Net Present Value (NPV)
- Internal Rate of Return (IRR)

Risk sources (difficult to analyze separately):

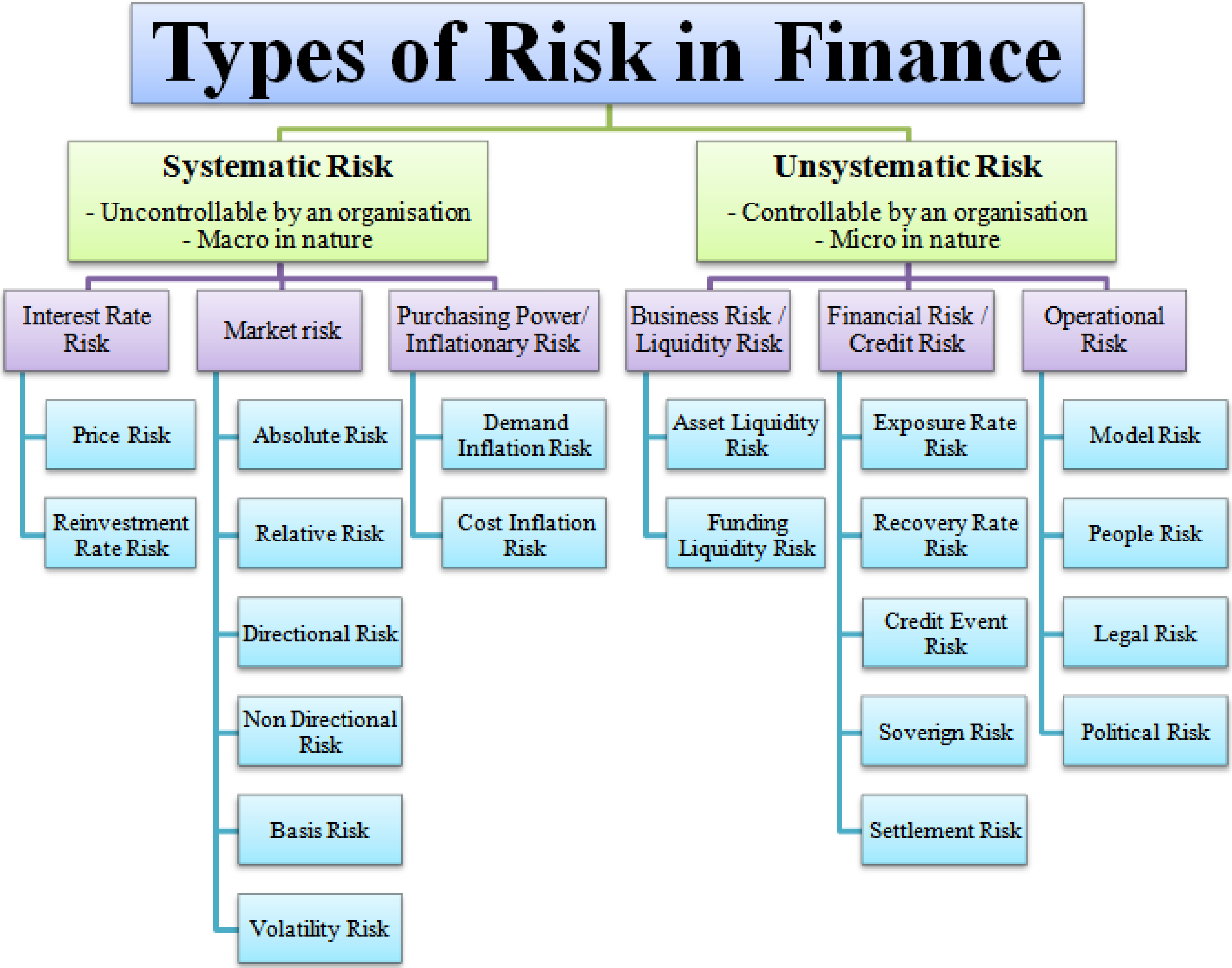
- Microeconomic factors
  - company
- Mezoeconomic factors
  - industry
- Macroeconomic factors
  - politics, world trends

Sources of Risk (2)

- **Country-Specific Economic risk**
  - *Macroeconomic Risks:*
    - Exchange rate;
    - Hyperinflation;
    - Terms of Trade;
    - Debt Service.
  - *Microeconomic Risks:*
    - *Market Failure;*
    - *Market Inefficiency.*
  - *Supranational Level* → risk of contagion!

Risk type:

- Systematic risk
  - originates from macroeconomic risk groups
  - ever-present, cannot get rid of
  - reduction is possible only to a certain (limited) extent
- Specific (unsystematic) risk
  - due to specific nature of investment


Types of Risk in Finance
Systematic Risk
- Uncontrollable by an organisation
- Macro in nature
Unsystematic Risk
- Controllable by an organisation
- Micro in nature
Interest Rate Risk
Market risk
Purchasing Power/ Inflationary Risk
Business Risk / Liquidity Risk
Financial Risk / Credit Risk
Operational Risk
Price Risk
Reinvestment Rate Risk
Absolute Risk
Relative Risk
Directional Risk
Non Directional Risk
Basis Risk
Volatility Risk
Demand Inflation Risk
Cost Inflation Risk
Asset Liquidity Risk
Funding Liquidity Risk
Exposure Rate Risk
Recovery Rate Risk
Credit Event Risk
Soverign Risk
Settlement Risk
Model Risk
People Risk
Legal Risk
Political Risk

Market vs. specific risk

(Total) Risk

Specific Risk
(Unique, residual,diversifiable)

Affects a particular company and can be reduced by diversification

- A competitor patents new technology
- The union at a production plant walks out on strike
- A major new competitor enters the industry

Specific risk should be reflected in the forecasted cash flows, not in the discount rate

Systematic Risk
(Market Risk)

Affects all companies and cannot be reduced by diversification

- Inflation rises unexpectedly
- Political instability, war…
- Federal Reserve raises interest rates
- Industrial or economic cycle changes

Market risk should be reflected in cash flows and the cost of capital. It cannot be diversified away and investors want to be compensated for bearing it

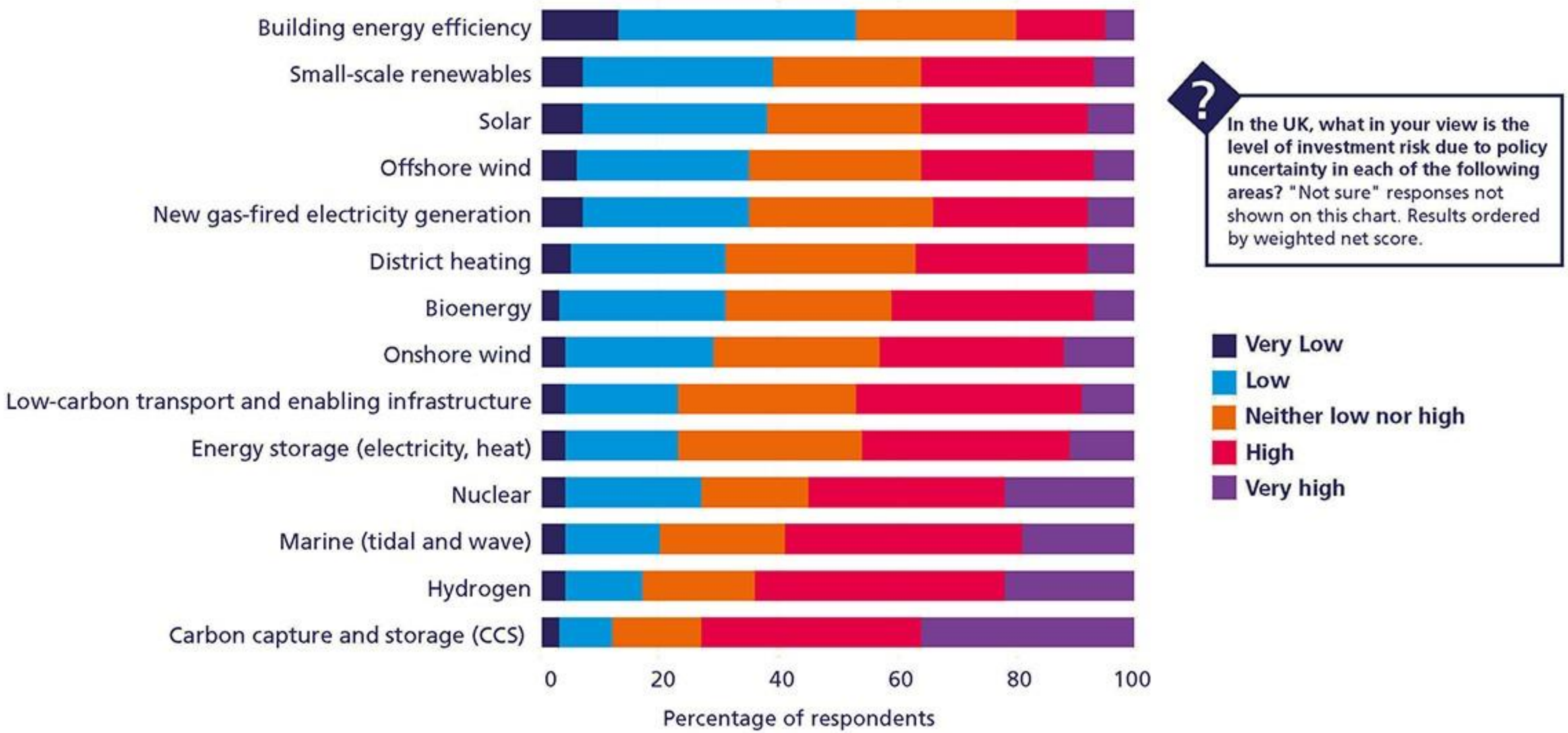
Systematic Risk vs. Specific Risk

- Flood – Systematic Risk -everyone gets wet
- Bucket of water thrown by your brother – Specific risk – only you get wet

- Insuring one House – Systematic or Specific?
- Insuring thousands of houses – Systematic or Specific?

5

Level of investment risk from policy uncertainty



©Energy Institute, Energy Barometer 2017

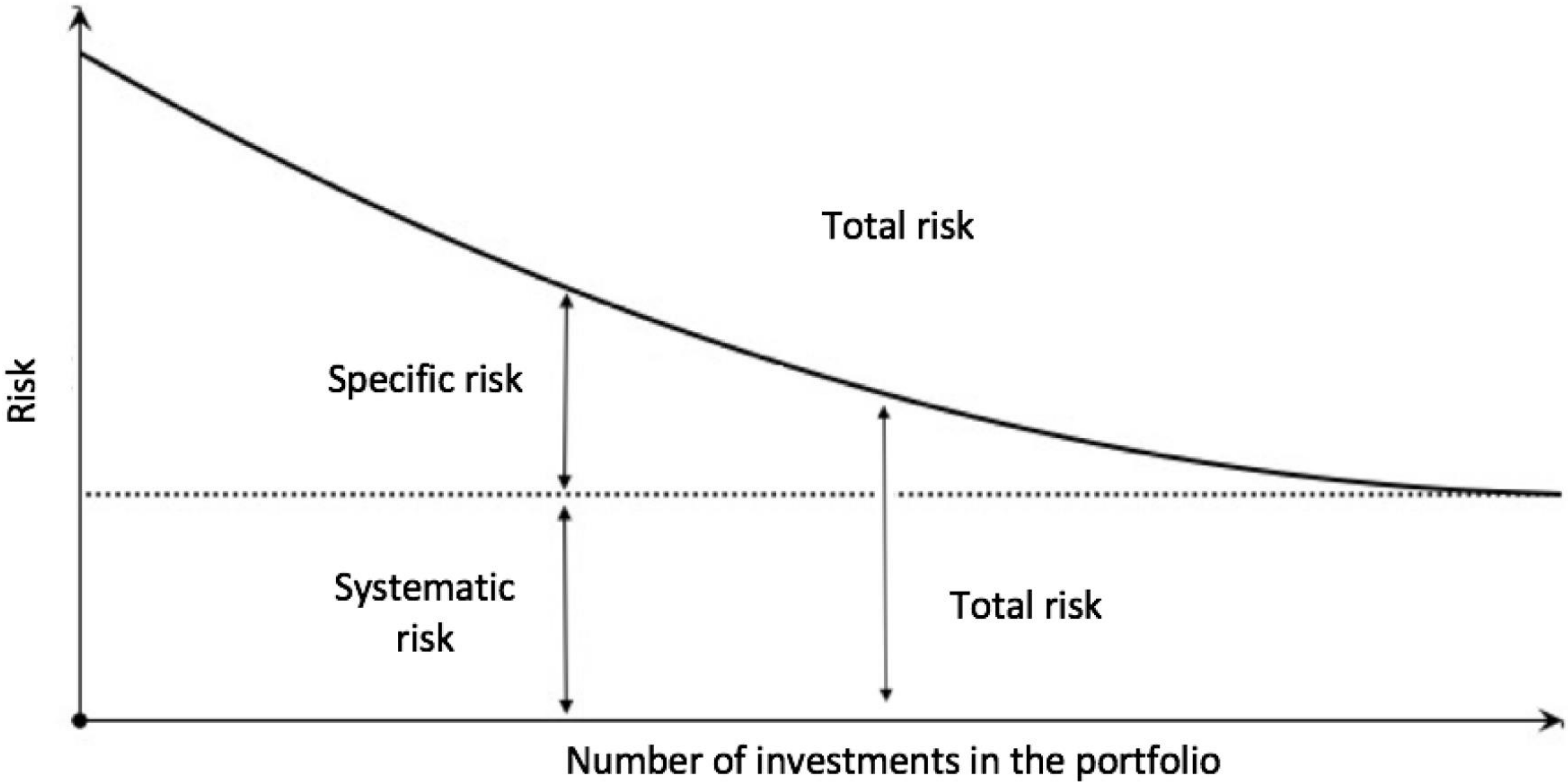
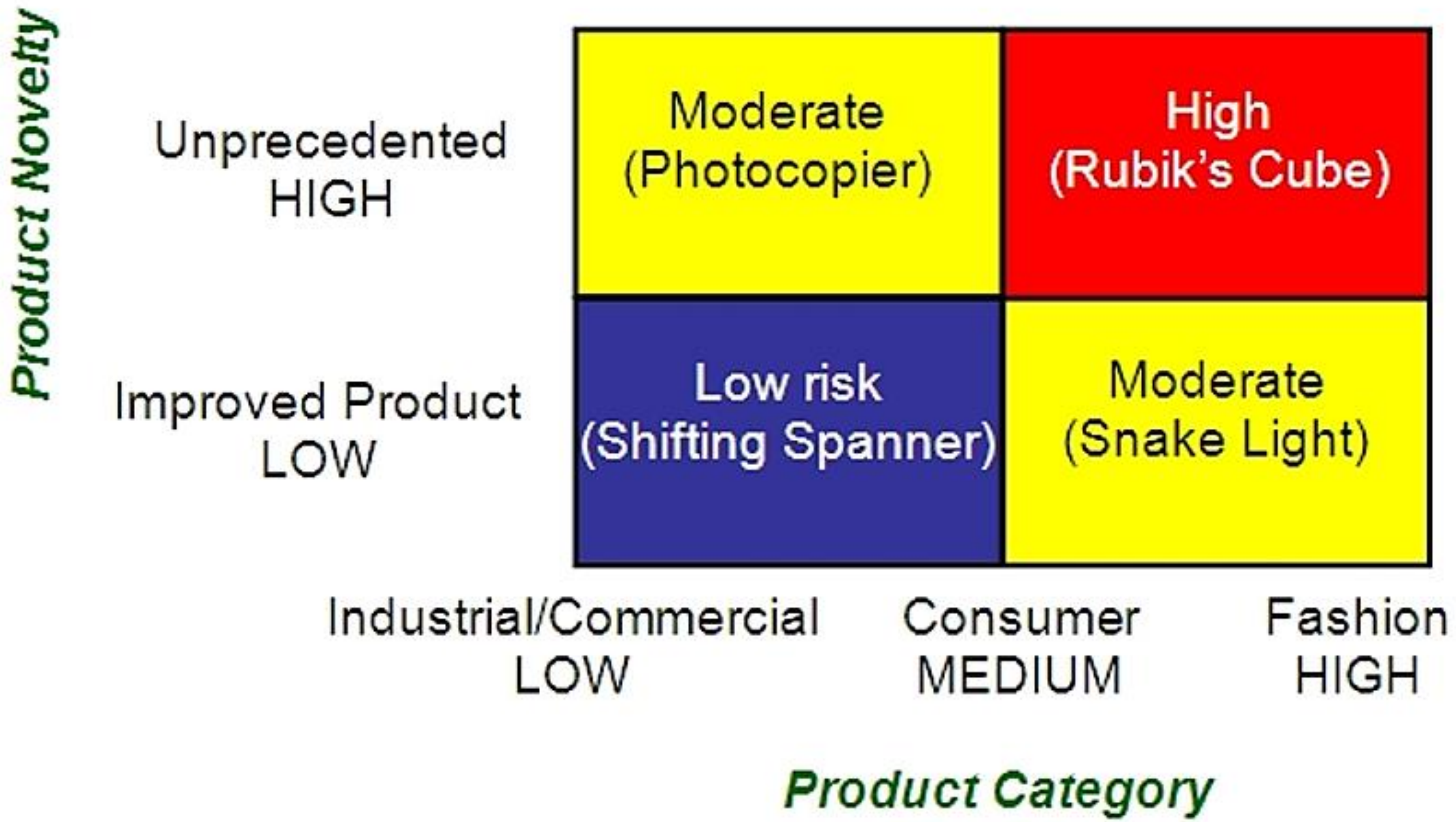


Fig. 1. The impact of diversification on the level of risk (Kryzia 2014)

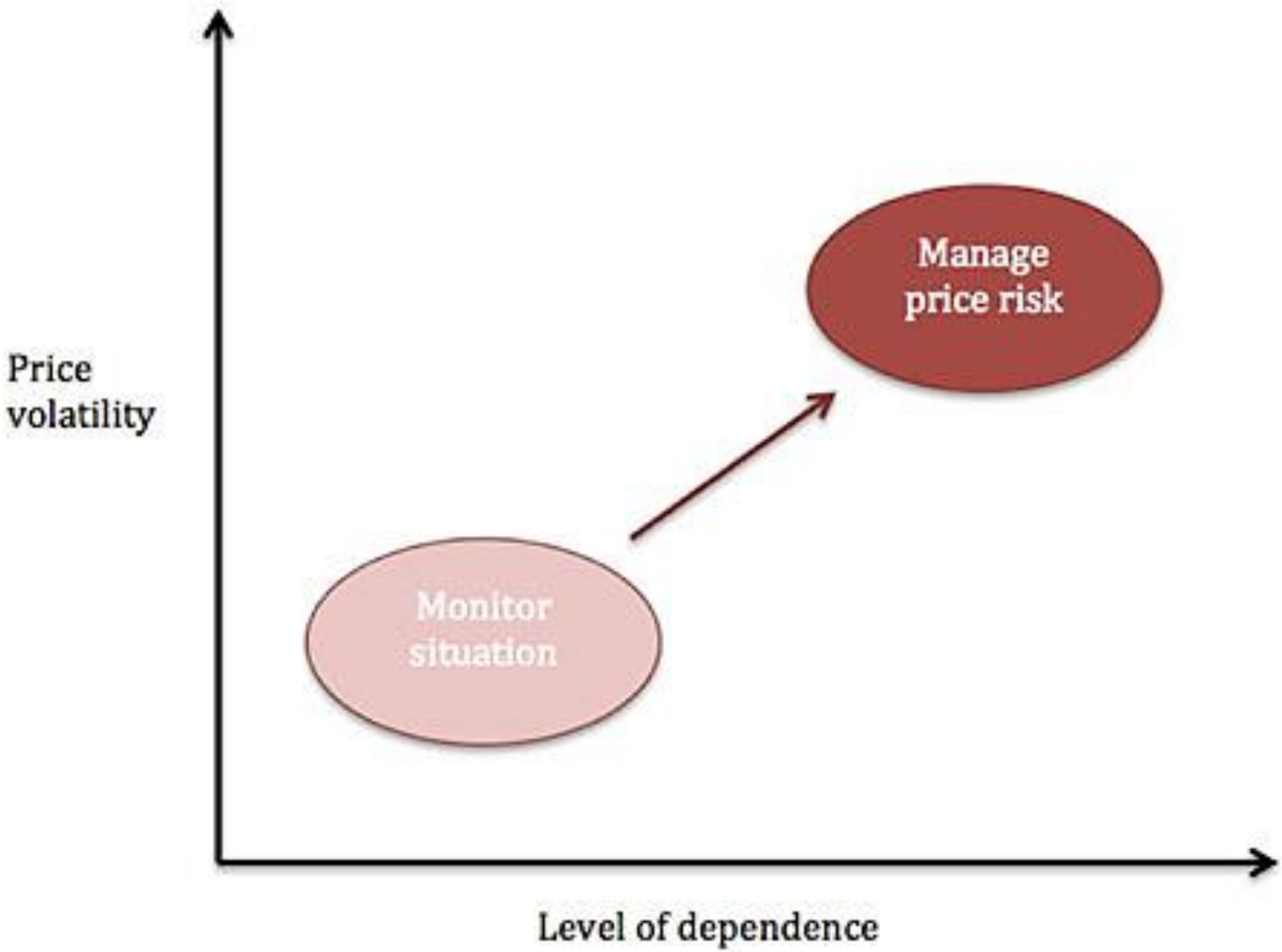
Types of investment risk in the energy sector (depending on specificity and uniqueness of investment):

- Market risk
  - Normally, no single investment affects the balance of a mature market
  - Theoretically, quantity and price determine success
  - In reality, participation in market may be prevented by competition
  - Such market risk may relate to supply, demand, market competition or price

Market Risk Map



- Price risk
  - Changing price of a product
  - Changing cost of components of a product
    - Emission allowances
    - Price of fuel/energy (electricity)
    - Cost of certification
    - Cost of labor


Manage
price risk
Price
volatility
Monitor
situation
Level of dependence

- Political risk (*more later*)
  - Difficult to estimate and diversify
    - Tariff policy
    - Regulation policy
    - Warranty policy
    - Industry regulations
  - Legal risk subcategory
    - Overregulation, e.g. too many regulations
    - Underregulation, e.g. insufficient (legal) description of aspect
    - Dynamic legal developments (especially with long-term investments)
  - Paper focuses on risks that are marginally political/ir

Examples of Political Risk

Below are some examples of political risk and can be broken down into separate Categories:

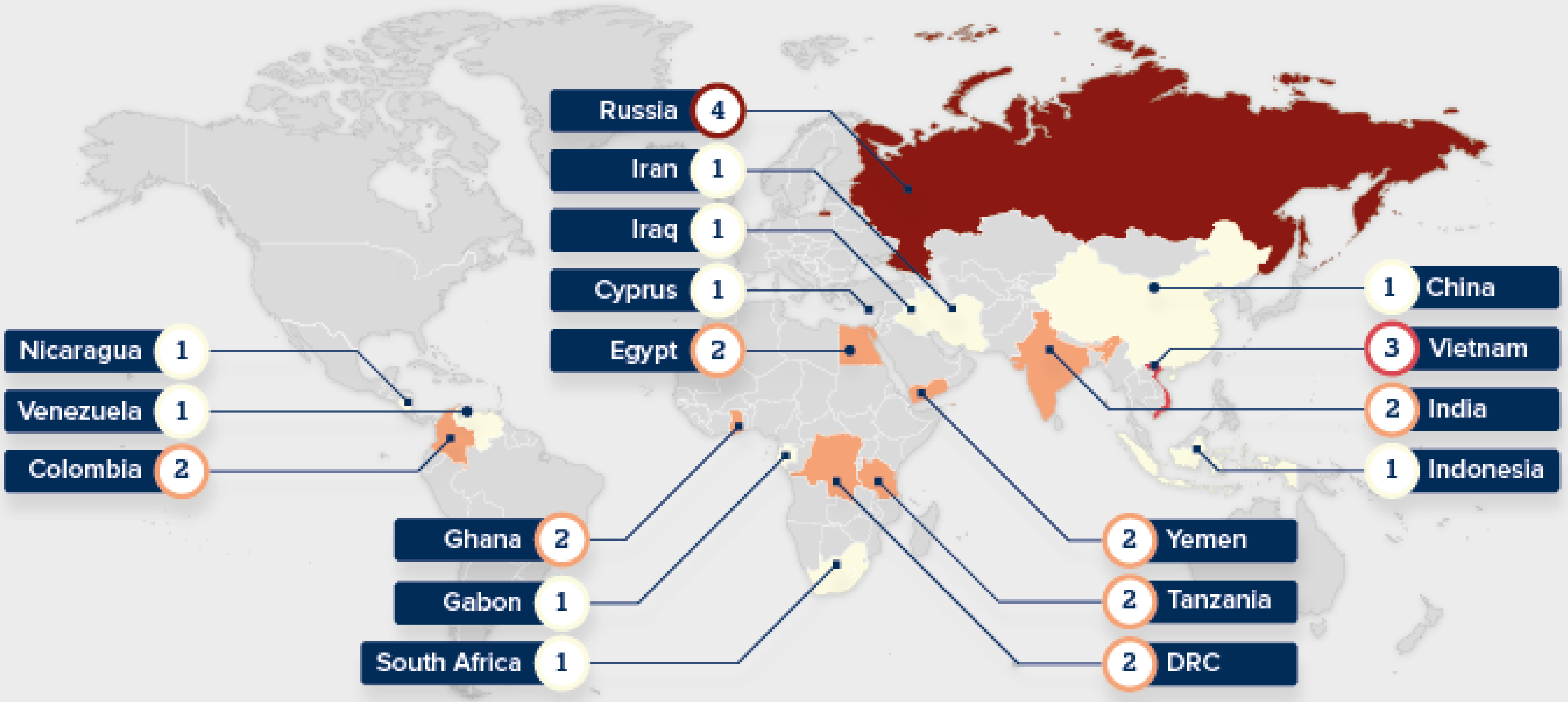
1. **Macro Risk** - Country Related

2. **Micro Risks** - Sector related

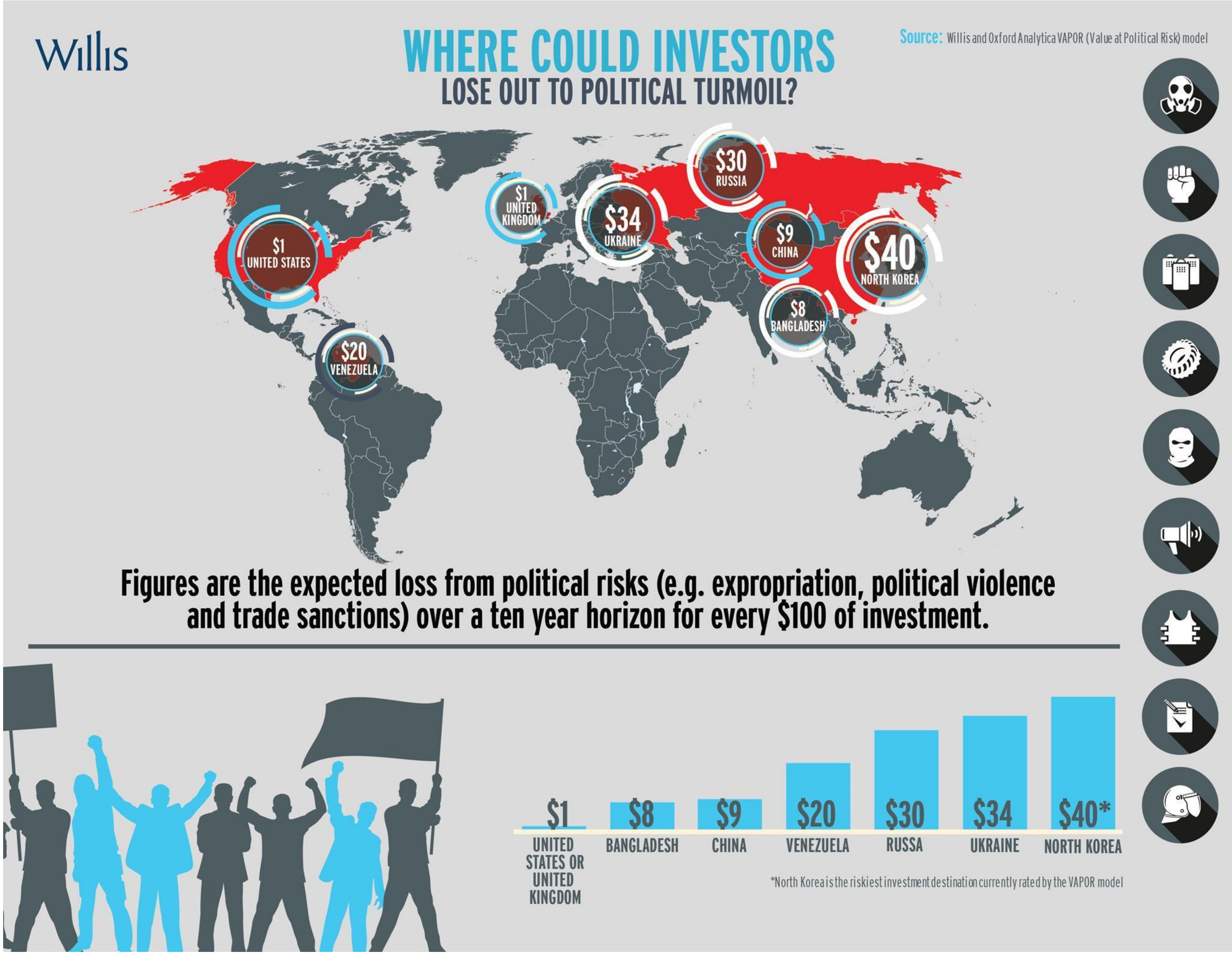
Examples of Risk
- High levels of crime and violence
- Terrorism
- Nationalisation of property
- Disorderly political manifestations, civil unrest and riots
- Armed conflict
- Foreign threat of invasion
- Weak political institutions
- High levels of corruption
- Large and unpredictable changes in government policy

In which countries did you experience political risk losses?

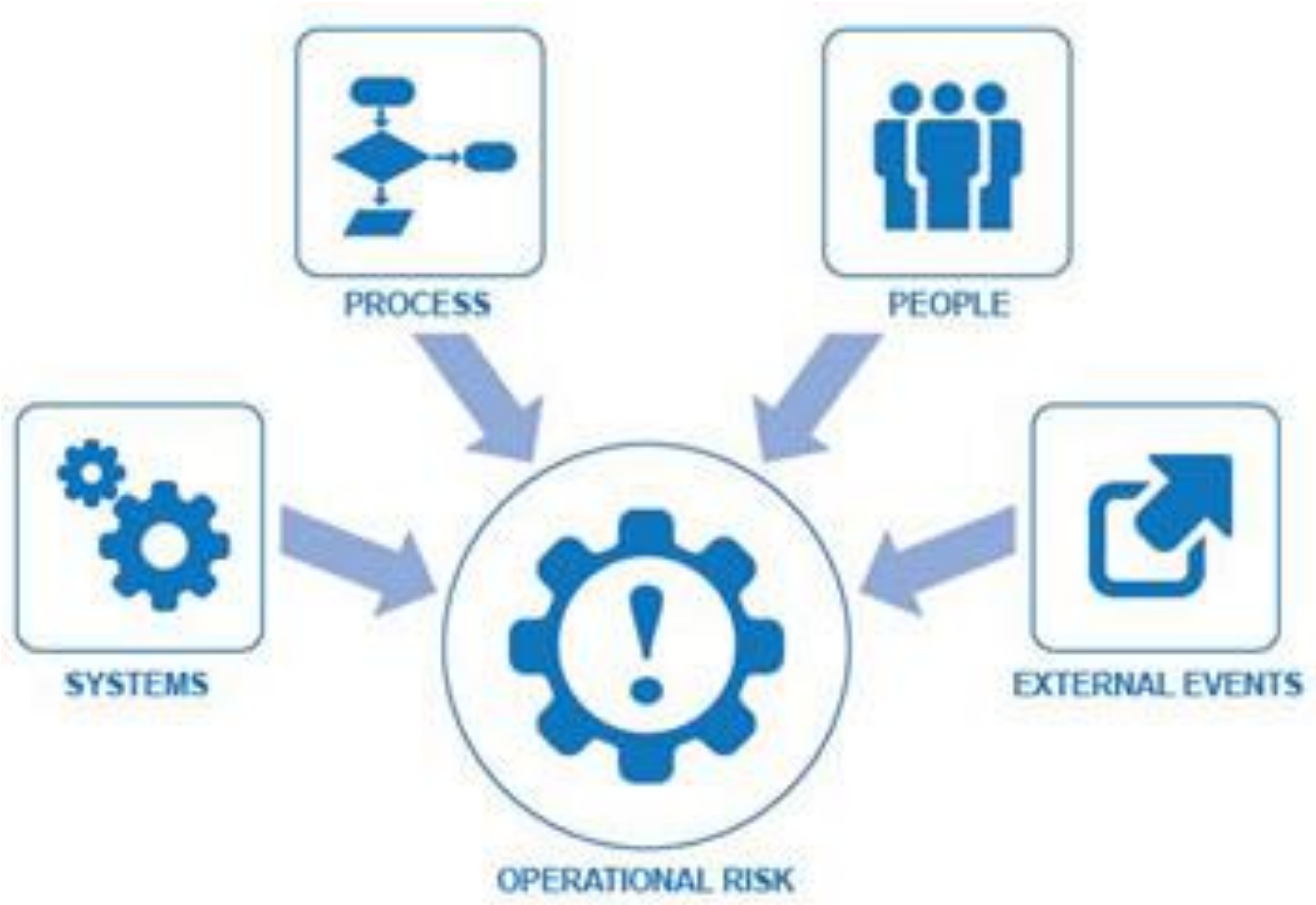
Note: Companies experiencing political risk losses only; ranked by number of mentions

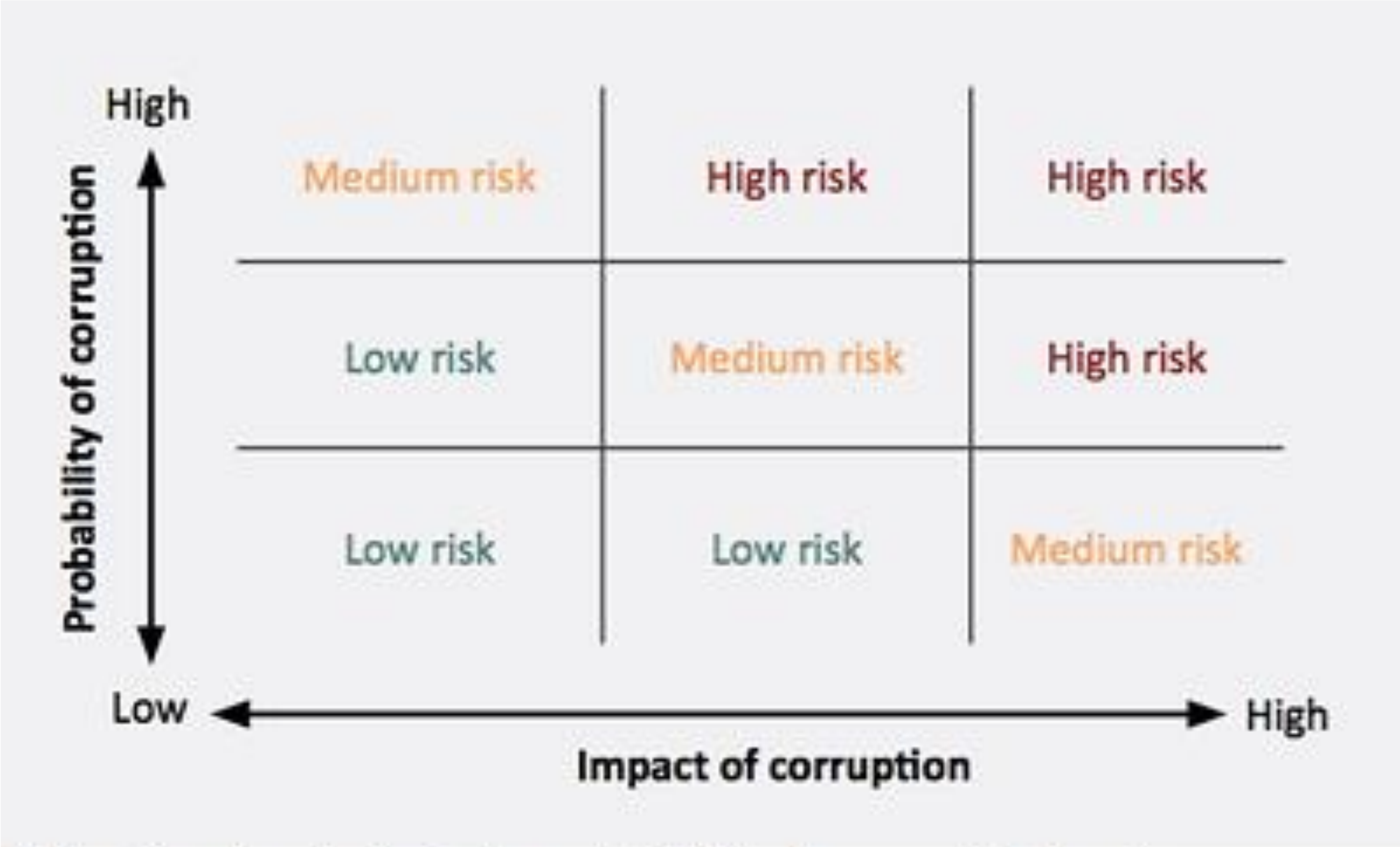


Source: Oxford Analytica


Willis
WHERE COULD INVESTORS
LOSE OUT TO POLITICAL TURMOIL?
Source: Willis and Oxford Analytica VAPOR (Value at Political Risk) model
$1 UNITED STATES
$1 UNITED KINGDOM
$34 UKRAINE
$30 RUSSIA
$9 CHINA
$40 NORTH KOREA
$8 BANGLADESH
$20 VENEZUELA
Figures are the expected loss from political risks (e.g. expropriation, political violence and trade sanctions) over a ten year horizon for every $100 of investment.
$1 UNITED STATES OR UNITED KINGDOM
$8 BANGLADESH
$9 CHINA
$20 VENEZUELA
$30 RUSSA
$34 UKRAINE
$40* NORTH KOREA
*North Korea is the riskiest investment destination currently rated by the VAPOR model

- Financial risk
  - Investment not being profitable
    - Cash flow disturbances
- Operational risk
  - Improper management of company resources
    - Human
    - Technical
    - Financial
    - Disturbances in internal structure of company
    - Dishonesty of employees or shareholders (corruption)


PROCESS
PEOPLE
SYSTEMS
EXTERNAL EVENTS
OPERATIONAL RISK



Estimating level of risk: probability by expected impact

CORRUPTION RISK ASSESSMENT

(Ernst & Young Global Ltd., 'Bribery and Corruption: Navigating the Global Risks', 2012)

- company's geographic location(s)
- business sectors scoped
- business partners + nature of activities & transactions
- interactions between partners & local officials

- Environmental risk
  - Impacts on ecosystems
  - Can incur social (external) costs or fines
- Construction risk
  - Postponing project milestones
  - Failure to meet completion schedule
  - May affect financial liquidity
- Technical risk
  - Improper operation
  - Unavailability (of infrastructure, e.g. Power grid, generating unit)

Technical risks

- *Threaten the quality and timeliness of of the software to be produced.*
- *If a technical risk become a reality ,implementation may become difficult and impossible.*
- *Technical risks occur when the problem is harder to solve than you thought it would be.*

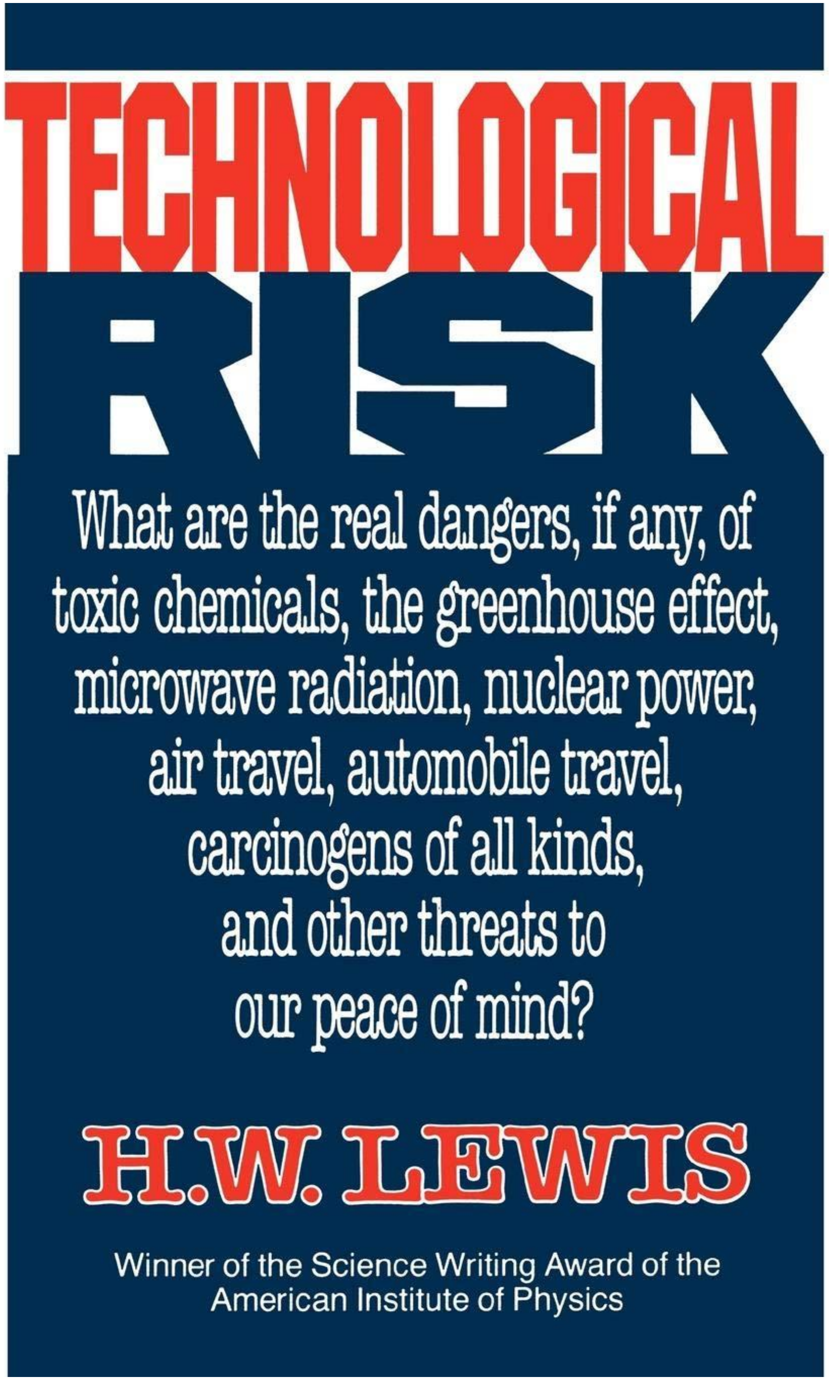
- ***Risk factors:***
  - ***Potential design and implementation***
  - ***Interface***
  - ***Verification***
  - ***Maintenance problems***
  - ***Specification ambiguity***
  - ***Technical uncertainty***

- Credit risk
  - ✖ Excessive debt
  - ✖ Lack of liquidity
  - ✖ Wrong decision on credit or equity funding
  - ✖ Large-budget energy infrastructure investments particularly prone to this type of investment risk
- Technological risk
  - ✖ Inability to find innovative solutions
  - ✖ Emergence of new more efficient technology

Technological Risks

The contractor

- ✓ Does not assign capable or adequate resources
- ✓ Is not familiar with the existing technology, application area of set up
- ✓ Does not follow a proven methodology
  - ☛ Either in project or technology management
- ✓ Does not use project management techniques
  - ☛ To track progress or identify issues
- ✓ Is not close at hand to facilitate coordination
  - ☛ With the client and the users


TECHNOLOGICAL
RISK
What are the real dangers, if any, of toxic chemicals, the greenhouse effect, microwave radiation, nuclear power, air travel, automobile travel, carcinogens of all kinds, and other threats to our peace of mind?
H.W. LEWIS
Winner of the Science Writing Award of the American Institute of Physics

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Critical risks impacting the energy industry (https://riskandinsurance.com/7-risks-impacting-energy-industry/):

- Global warming/climate change
  - *"One of the biggest contributors to the greenhouse effect causing global warming is fossil fuel emission — of which, 80 percent of the world's energy comes from"*
- Rapidly changing industry
- Cyber threats
  - More when we look at the *history of energy security*
- Regulation and public policy
- Tariffs and trade tension
- Personnel issues (talent retention and new hires)
  - Retirement
- Catastrophic events (black swan, *more later*)
  - *"More events, more to them"*

Methods of risk identification:

- Checklists
  - Questions answered by experts
  - Success depends on accuracy and completeness of questions
- Delphi method
  - Panel of experts from various fields
  - Working in isolation is advised
  - Collected and systematized results are presented to the group

Delphi defined as….

- An "organized method" for collecting views and information pertaining to a specific area;
- A method that allows dialogue between geographically separated experts while serving an effective means for learning;
- Gathering a group of experts to forecast events and assess complex issues;
- Collective human intelligence;
- A process of exploring… assessing… and evaluating.

The Wisdom of Crowds

- Idea was popularized by a book published in 2004 called *The Wisdom of Crowds* by James Surowiecki

- A diverse collection of independently-deciding individuals is likely to make certain types of decisions and predictions better than individuals or even experts

- The aggregation of information in groups resulted in decisions that are often better than could have been made by any single member of the group

- This book presented numerous case studies that touch several fields, primarily economics and psychology.

- Delphi Method, Prediction Markets, County Fair example

A *NEW YORK TIMES* BUSINESS BESTSELLER

"As entertaining and thought-provoking as *The Tipping Point* by Malcolm Gladwell. . . . *The Wisdom of Crowds* ranges far and wide."
—*The Boston Globe*

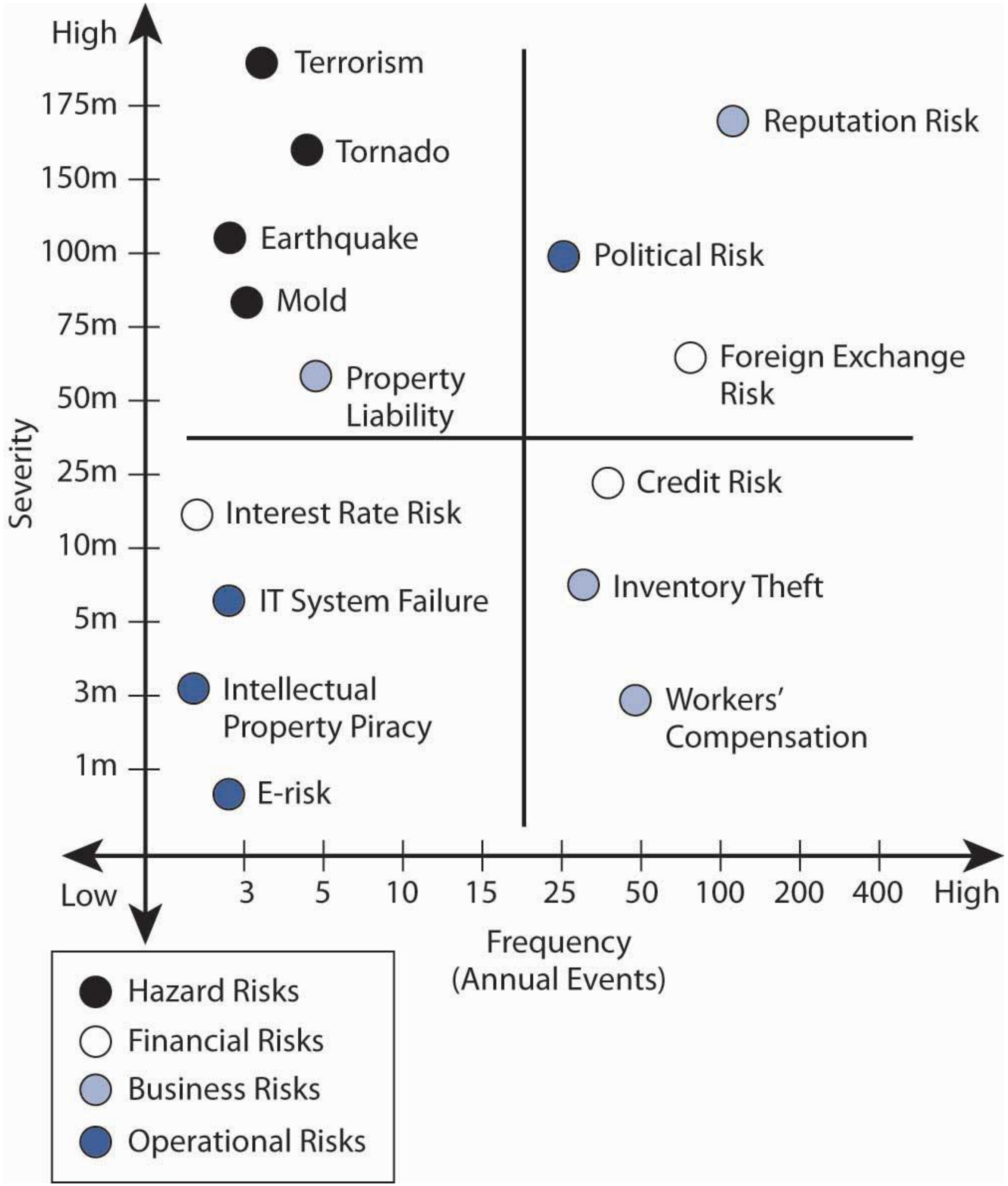
THE WISDOM OF CROWDS

JAMES SUROWIECKI

WITH A NEW AFTERWORD BY THE AUTHOR

- <u>Nominal group</u> technique
  - Similar to Delphi method
  - Experts work in groups
- <u>Brainstorming</u> and <u>public debate</u>
  - Joint discussion on given issue
  - Best possible solution sought
  - Public debate = special form of brainstorming
    - Both supporters and opponents of an investment may be present

- Holistic methods
  - Large drawing analysis
    - Legal and technical dependencies
    - Interpersonal relations
    - Potential conflicts
  - Map of system
    - All potential relationships between the elements of an investment
  - Formal model
    - Formal relationships between elements of an investment


High
Terrorism
175m
Tornado
150m
Reputation Risk
Earthquake
100m
Political Risk
Mold
75m
Property Liability
50m
Foreign Exchange Risk
Severity
25m
Credit Risk
Interest Rate Risk
10m
IT System Failure
Inventory Theft
5m
Intellectual Property Piracy
3m
Workers' Compensation
1m
E-risk
Low
3
5
10
15
25
50
100
200
400
High
Frequency (Annual Events)
Hazard Risks
Financial Risks
Business Risks
Operational Risks

Risk Identification Tools

- Checklists, questionnaires, surveys
- Personal Interviews
- Performance standards checks
- Process flow analysis – routine inspections and quality control measures
- Audits – both internal and external
- Specialized Computer software
- Team approaches – brainstorming
- Claims history
- Insurance records

Risk Identification Techniques

- Interview with SME's
- Brainstorming
- Delphi Technique
- Nominal Group Technique
- Crawford Slip
- Analogy
- SWOT
- Cause & Effect Diagram

Methods of reducing risk:

- <u>Avoid</u> risk
  - Discontinue investment in high risk projects
- <u>Reduce</u> risk
  - Diversify = spread risk into many investments/projects
  - Compensate = hedging
- <u>Transfer</u> risk to insurer or subcontractors
- <u>Finance</u> risk = cover risk with equity

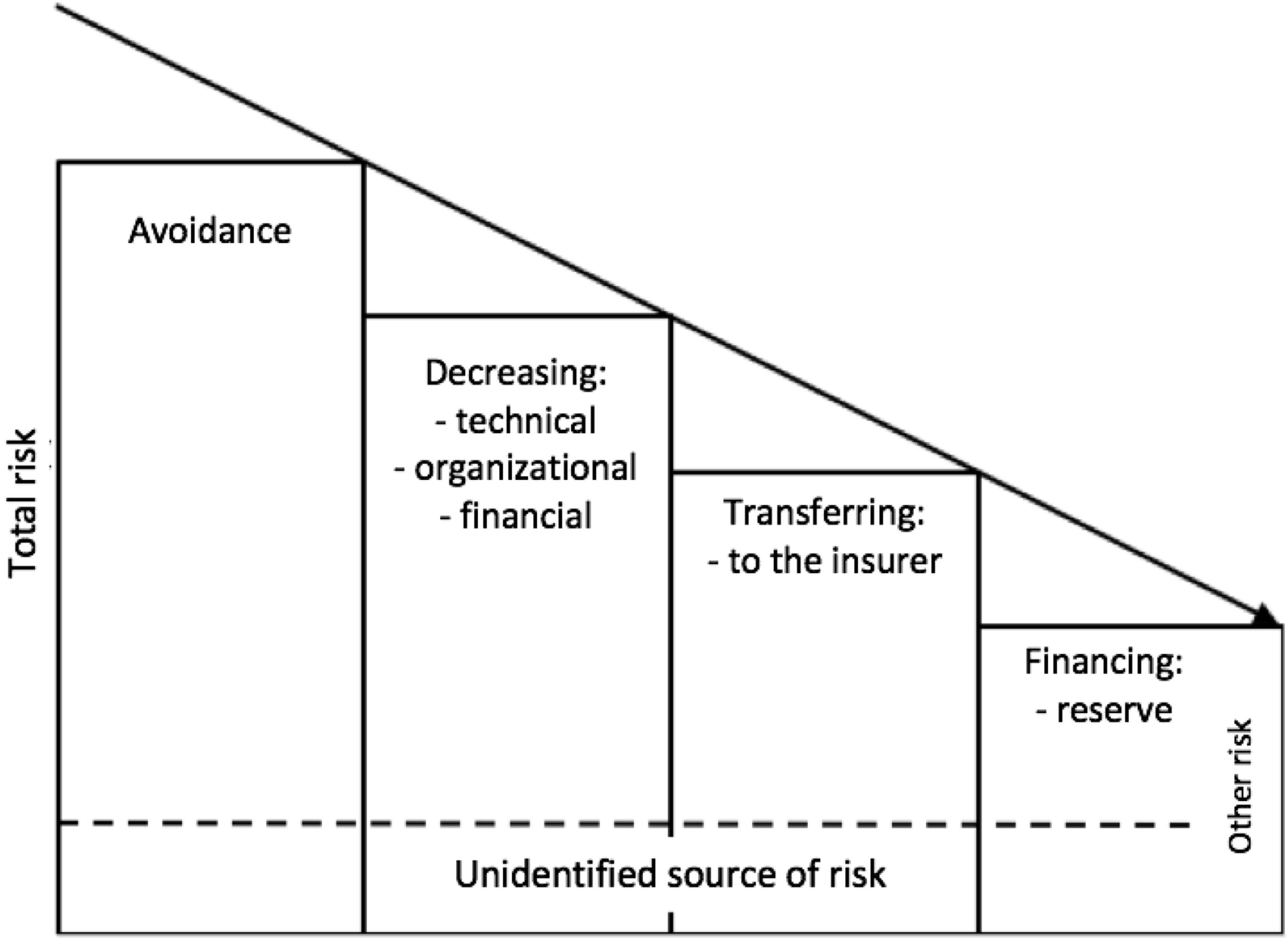


Fig. 2. Risk management (Zachorowska 2006)

Let’s introduce some insurance concepts into the presentation

Pure vs speculative risk

- **Pure risk**: Situations where there are only two possibilities: loss or no loss (e.g. a fire at a solar farm), without the likelihood of gain
  - This is the only type insurance companies will underwrite
- **Speculative risk**: Situations where there is a chance for gain, loss, or staying the same (e.g. investing in a new energy startup)
  - Insurance does not cover these because they are part of business gambles

Static vs dynamic risk

Static risk: Risks that occur even if the economy stays the same, often due to nature or human dishonesty (e.g. lightning strikes or theft)

These are predictable and easier to insure

Dynamic risk: Risks resulting from changes in the economy, technology, or consumer tastes (e.g. a new policy making hydrogen power cheaper than solar)

These are harder to predict and usually uninsurable

Fundamental vs particular risk

Fundamental risk: Risks that affect large groups or the entire economy (e.g. hyperinflation, war, or global climate shifts)

These are often handled by governments rather than private insurers.

Particular risk: Risks that affect only individuals or specific companies (e.g. a specific wind turbine breaking down)

Because they are localized, they are the bread and butter of the insurance industry

Subjective vs objective risk

- **Subjective risk**: A person’s internal gut feeling or mental attitude toward risk
  - Two people might face the same danger, but one feels terrified while the other feels safe
- **Objective risk**: The actual, measurable variation of actual loss from expected loss
  - This is what the Monte Carlo simulation calculates: the math of the risk regardless of how a person feels about it

Chance of loss

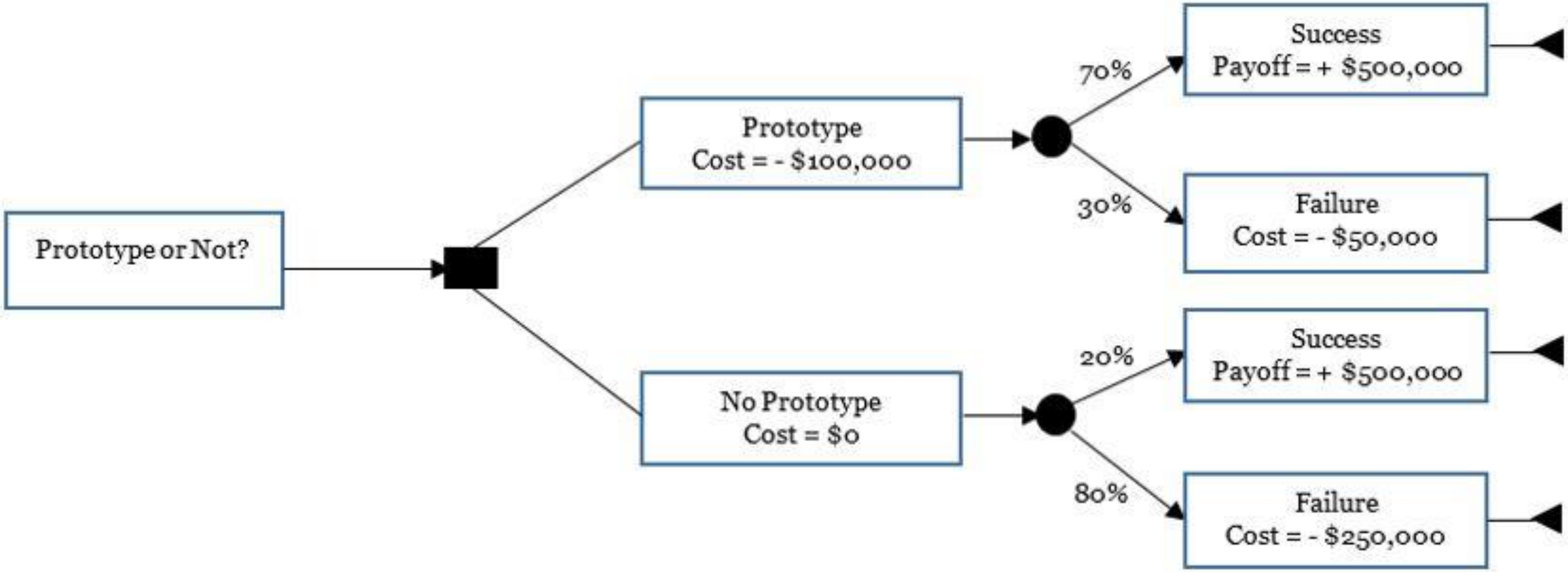
- The mathematical probability that a specific event will occur
  - Risk is the uncertainty of the outcome
  - Chance of loss is the actual percentage (e.g. a 5% chance that a hail storm will damage solar panels)

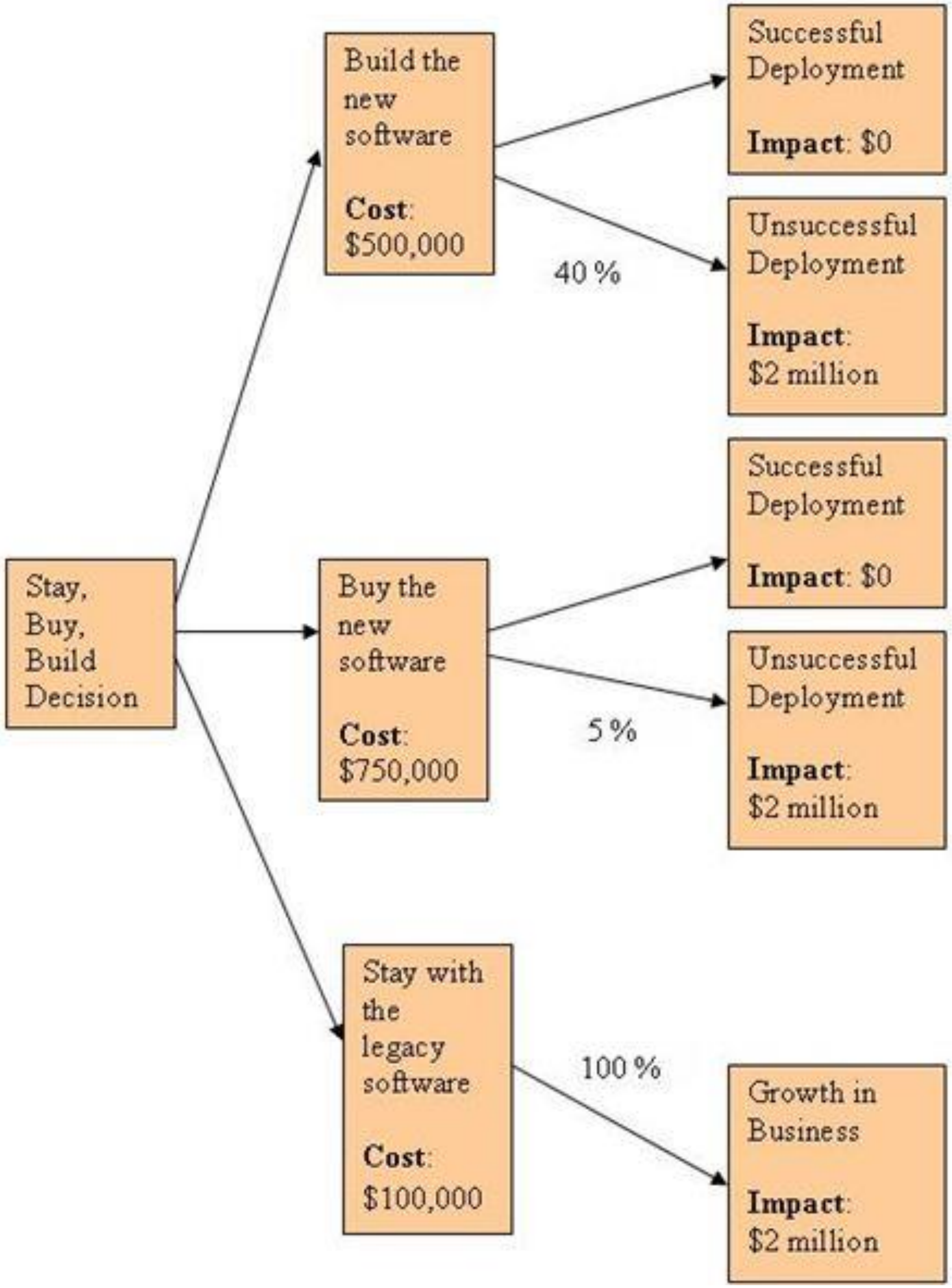
Hazards are the conditions that increase the frequency or severity of a loss

- **Physical hazard**: A tangible condition (e.g. building a battery storage facility in a flood zone)
- **Moral hazard**: Dishonesty or character flaws that lead a person to intentionally cause a loss to collect insurance (e.g. someone setting their own failing project on fire).
- **Morale hazard**: Carelessness or indifference to loss because insurance exists (e.g. *“I don't need to double-check the locks on the equipment because we’re insured anyway”*).

Methods of quantifying risk:

- Financial
  - Discount rate
    = standard (risk-free) rate + inflation + risk premium
  - Net Present Value (NPV)
  - Internal Rate of Return (IRR)
- Sensitivity (analysis)
  - Combined with financial (NPV & IRR) methods
- Decision making trees
- Networks
- Experts


Prototype or Not?
Prototype
Cost = - $100,000
No Prototype
Cost = $0
70%
30%
20%
80%
Success
Payoff = + $500,000
Failure
Cost = - $50,000
Success
Payoff = + $500,000
Failure
Cost = - $250,000


Stay, Buy, Build Decision
Build the new software
Cost: $500,000
Successful Deployment
Impact: $0
40 %
Unsuccessful Deployment
Impact: $2 million
Buy the new software
Cost: $750,000
Successful Deployment
Impact: $0
5 %
Unsuccessful Deployment
Impact: $2 million
Stay with the legacy software
Cost: $100,000
100 %
Growth in Business
Impact: $2 million

- Statistical
- Probabilistic
  - Value at Risk (var), uses statistical distributions
    - Historical method
    - Variance method
    - Monte Carlo method
- Simulation
  - Monte Carlo method = repeated sampling

Monte Carlo simulation is a mathematical technique used to understand the probability of different outcomes in a process that is hard to predict

Instead of using a single fixed number for a calculation, we use a range of possible values

Here are the steps of Monte Carlo (**1/3**)

- Identify the variables you cannot know for certain, e.g. the future price of raw materials or the exact time construction will finish
  - For each of these, define a minimum, a maximum, and a most likely value

Here are the steps of Monte Carlo (**2/3**)

- A computer takes these ranges and runs the project's financial model thousands of times (often more than 10,000)
  - In each run, the computer randomly selects a value for every variable within the ranges you provided
  - Then it calculates the final result for that specific combination of numbers

Here are the steps of Monte Carlo (**3/3**)

After thousands of runs, you are left with a collection of thousands of different possible results

A probability distribution has been defined!

By looking at all these results together, you can see which outcomes happened most often

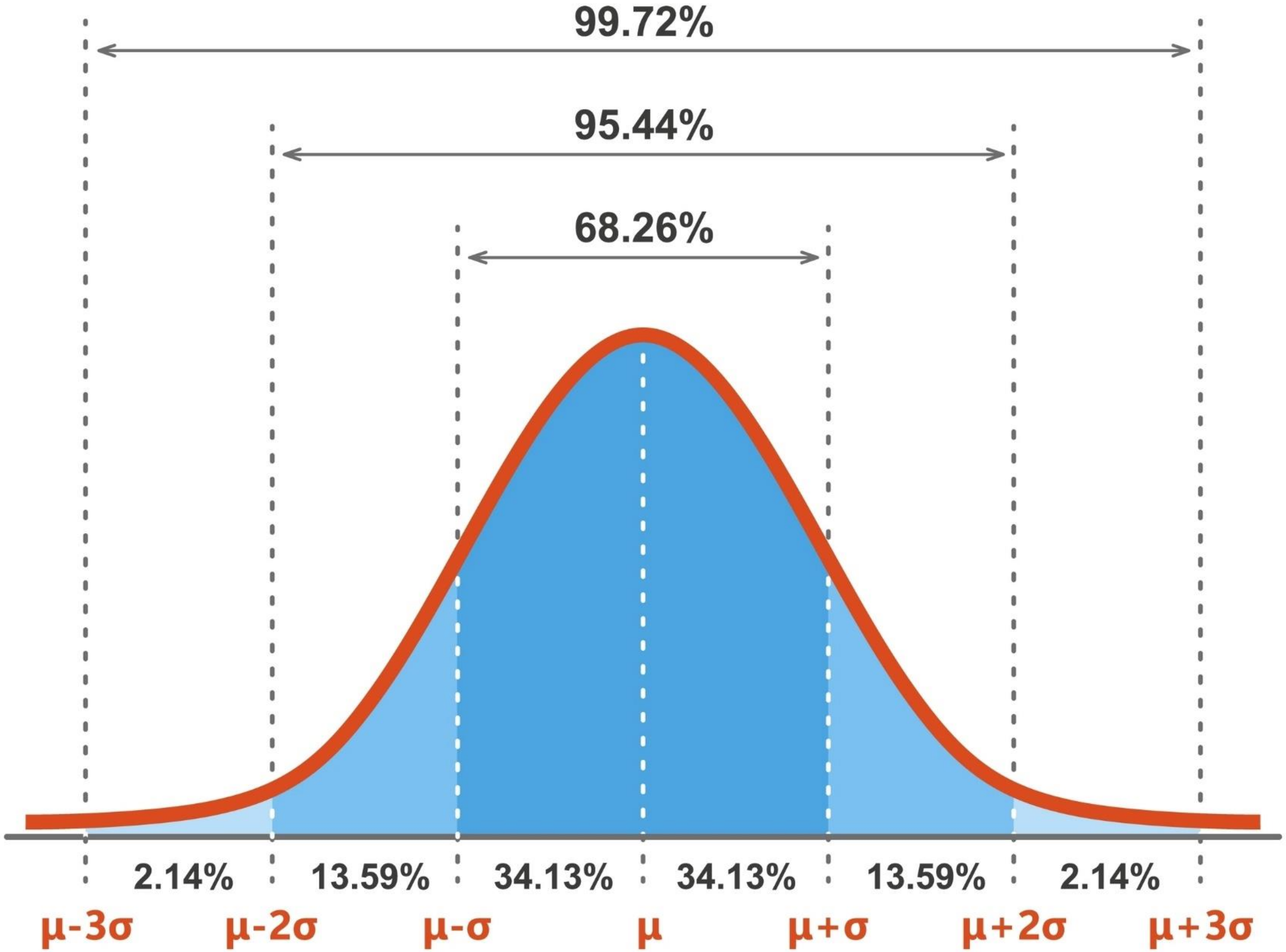
Risk assessment

Instead of saying *“the project will cost $100 million”* you can say *“there is an 85% chance the project will cost between $95 million and $105 million”*

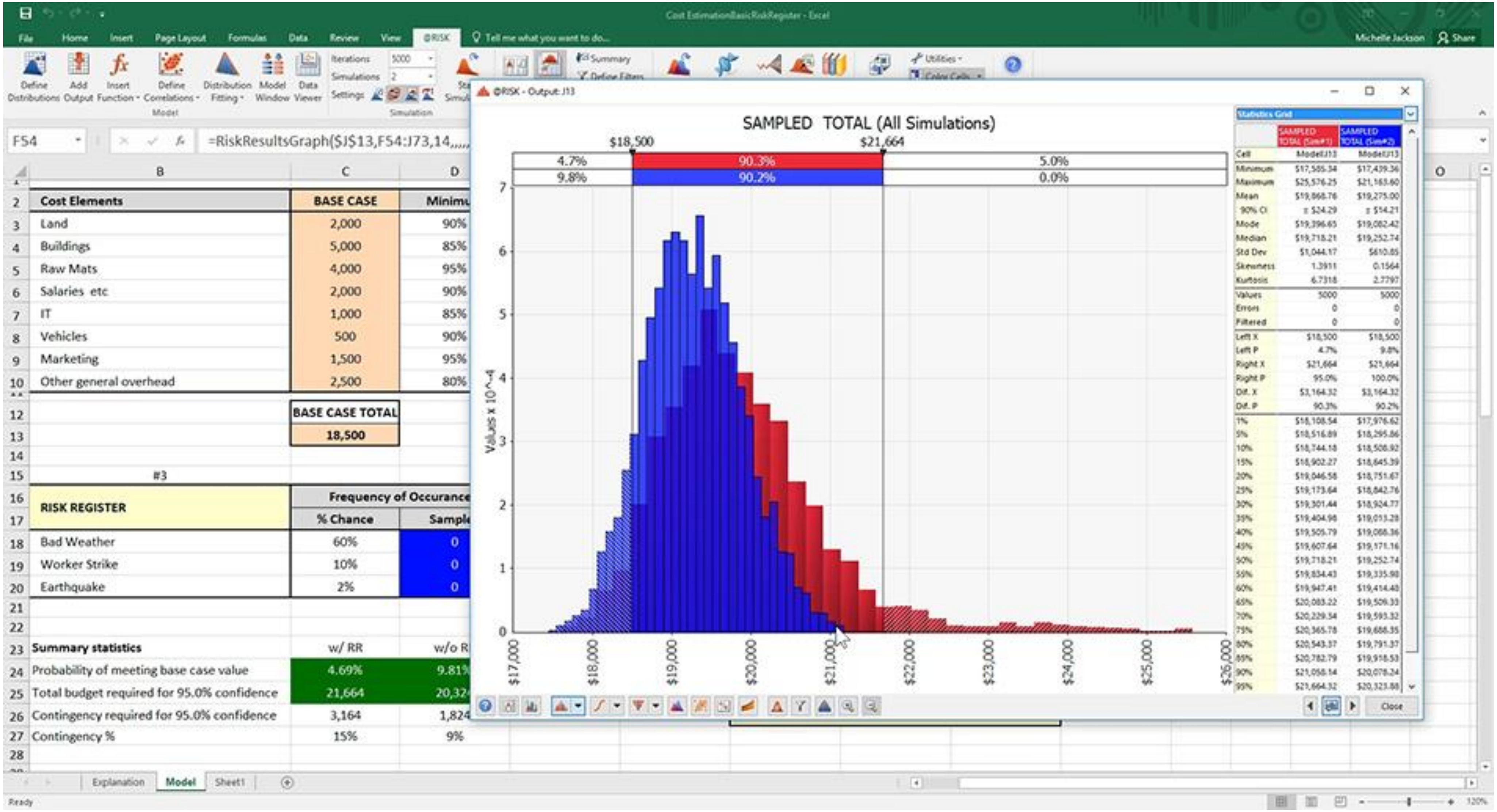
- Monte Carlo is essential for energy projects
  - Energy technology involves massive upfront costs (capital intensity), so small changes in variables (e.g. interest rates or supply chain costs) can have a huge impact
- Monte Carlo allows planners to see the full spectrum of financial risk and decide if the project is stable enough to proceed

Let's try a human Monte Carlo experiment in class

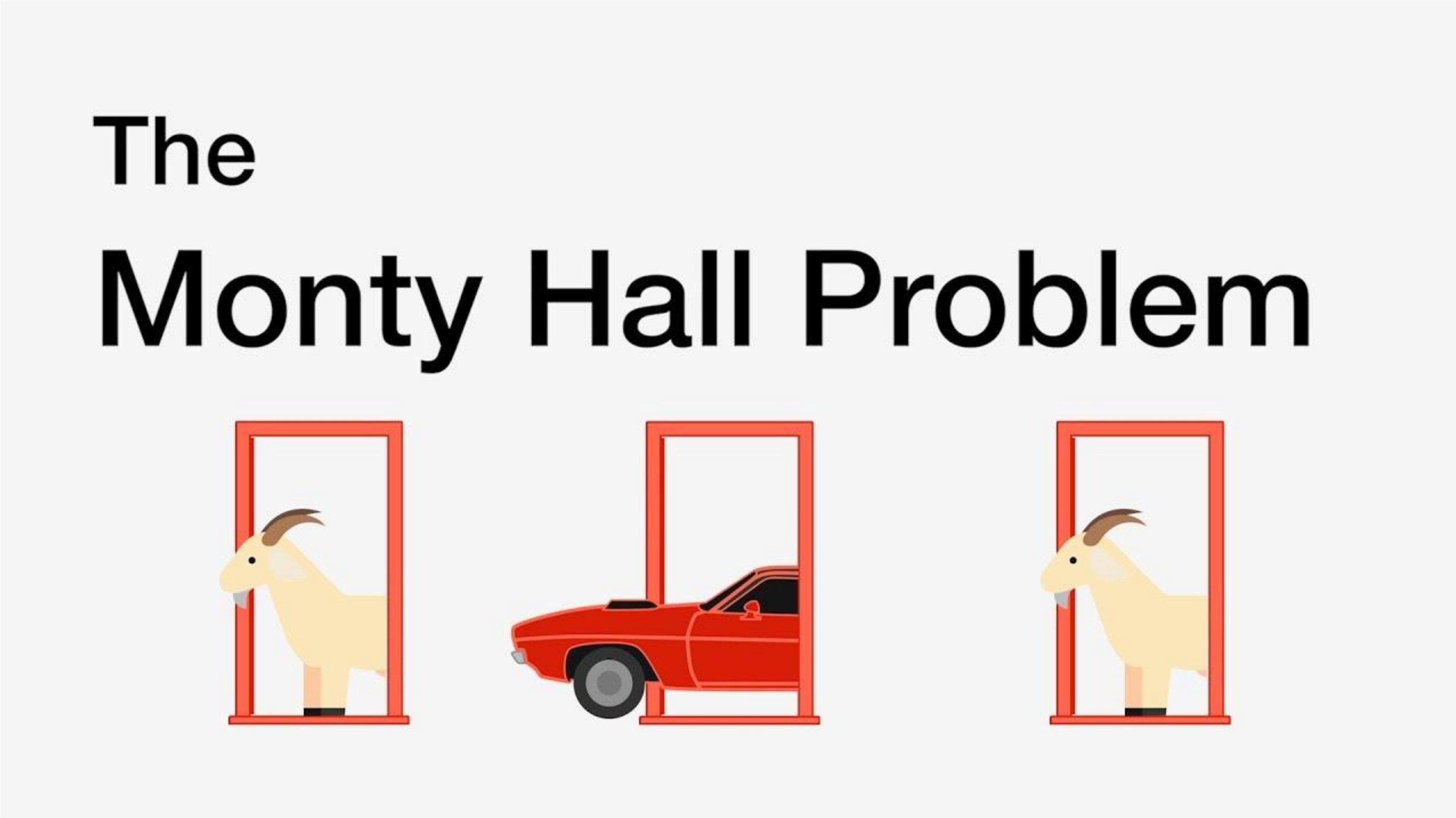
- The students are all project managers for the same solar farm
- The project has three main phases, but the time each phase takes is uncertain
    - (1) Permitting: Can take 1, 2, or 3 months
    - (2) Shipping materials: Can take 1, 2, or 3 months
    - (4) Installation: Can take 1, 2, or 3 months
- Students, please
    - Privately pick three random numbers between 1 and 3 by typing the following in Google
        - <u>pick a random number from 1 to 3</u>
    - Then add the three numbers together
    - Finally type your total sum into the chat when I give the signal
        - It should be a single integer number between 3 and 9


99.72%
95.44%
68.26%
2.14%
13.59%
34.13%
34.13%
13.59%
2.14%
μ-3σ
μ-2σ
μ-σ
μ
μ+σ
μ+2σ
μ+3σ

- Let’s link Monte Carlo to insuring risk
  - Monte Carlo simulations help us measure objective risk
  - Insurance is the tool we use to protect against particular, pure risks
    - So that businesses have the confidence to take the speculative risks necessary for energy transition



=RiskResultsGraph(J13,F54:J73,14,,,,
Cost Elements
BASE CASE
Land
2,000
Buildings
5,000
Raw Mats
4,000
Salaries etc
2,000
IT
1,000
Vehicles
500
Marketing
1,500
Other general overhead
2,500
BASE CASE TOTAL
18,500
#3
RISK REGISTER
Frequency of Occurance
% Chance
Bad Weather
60%
Worker Strike
10%
Earthquake
2%
Summary statistics
w/ RR
w/o R
Probability of meeting base case value
4.69%
Total budget required for 95.0% confidence
21,664
Contingency required for 95.0% confidence
3,164
1,824
Contingency %
15%
9%
@RISK - Output: J13
SAMPLED TOTAL (All Simulations)
$18,500
$21,664
4.7%
90.3%
5.0%
9.8%
90.2%
0.0%
Values x 10^-4
$17,000
$18,000
$19,000
$20,000
$21,000
$22,000
$23,000
$24,000
$25,000
$26,000
Statistics Grid
Close
Explanation
Model
Sheet1
Ready



https://www.mathwarehouse.com/monty-hall-simulation-online/

Example of agricultural biogas plant:

- Mesophyll digestion,
- Single-stage fermentation,
- High performance cogeneration,
- The installed electrical capacity – 2 MW,
- The expected life – 20 years,
- The investment in the investor's premises,
- Substrates from animal husbandry carried out in the investor's farm,
- Corn silage and other vegetable waste available in the market at the price of PLN 80 /ton,
- The annual biogas plant operation time – 8000 h,
- Thermal efficiency – about 45%,
- Electrical efficiency – about 40%,
- The use of digestate pulp on own fields,
- The area adapted to the implementation of this type of investment,
- The unit cost is PLN 13 million/MW,
- Additional one-time costs of PLN 410 000.

The values characterizing the investment were calculated on the basis of the above assumptions. The gas production is around 7,300,000 m^3/ year (≈4 383 000 m^3 methane per year). The electric power is 2 MW and the thermal power is 2.25 MW, of which 9% and 21% are consumed for own needs of the system, respectively.

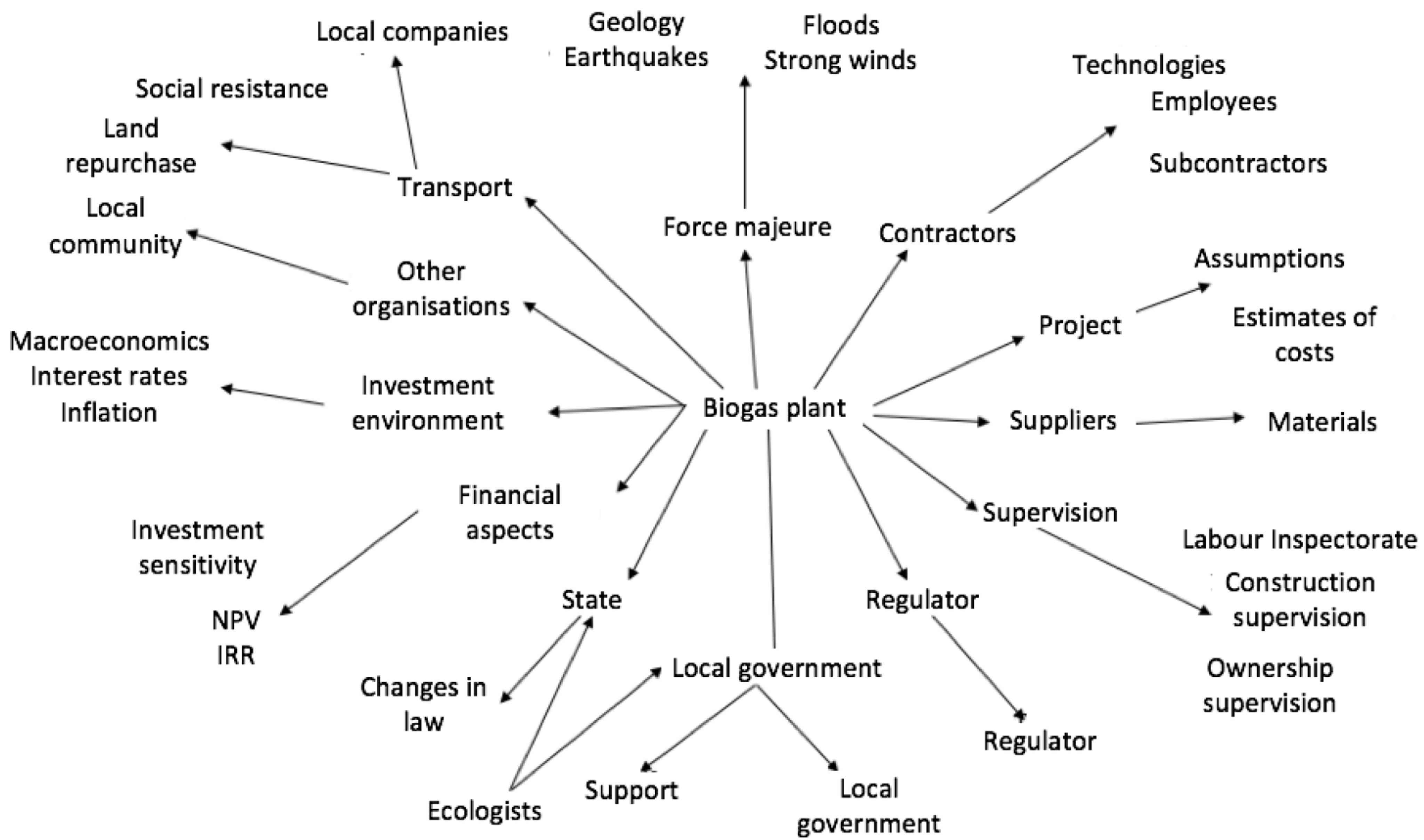


Fig. 3. The simplified "Large drawing analysis" for biogas plant

Example uses

- Monte Carlo simulation
- NPV indicator
  - 1000 random samples
  - NPV probability distribution
- VaR
  - 95% confidence level

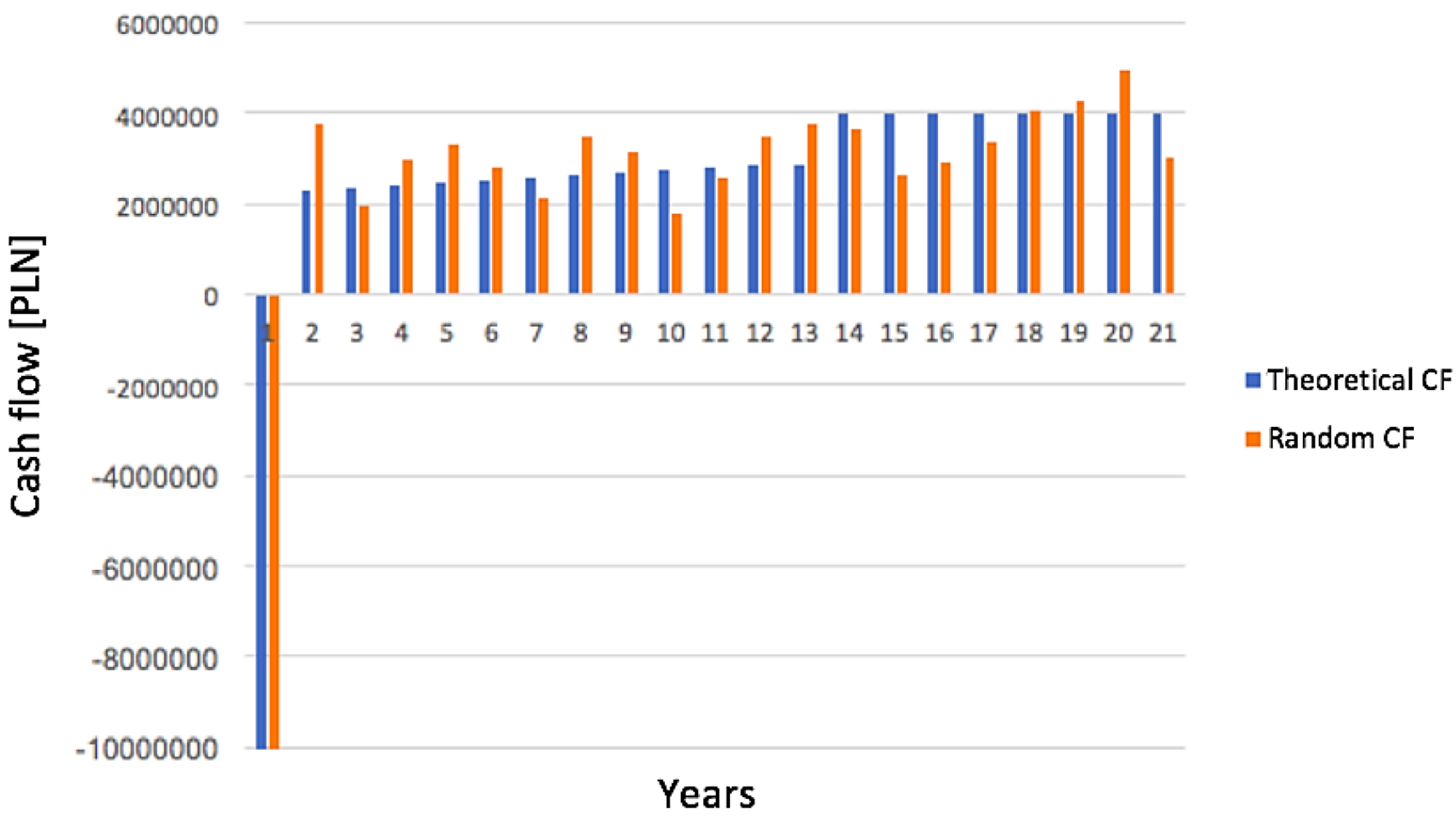


Fig. 4. The theoretical and exemplary, based on the Monte Carlo method, cash flow chart

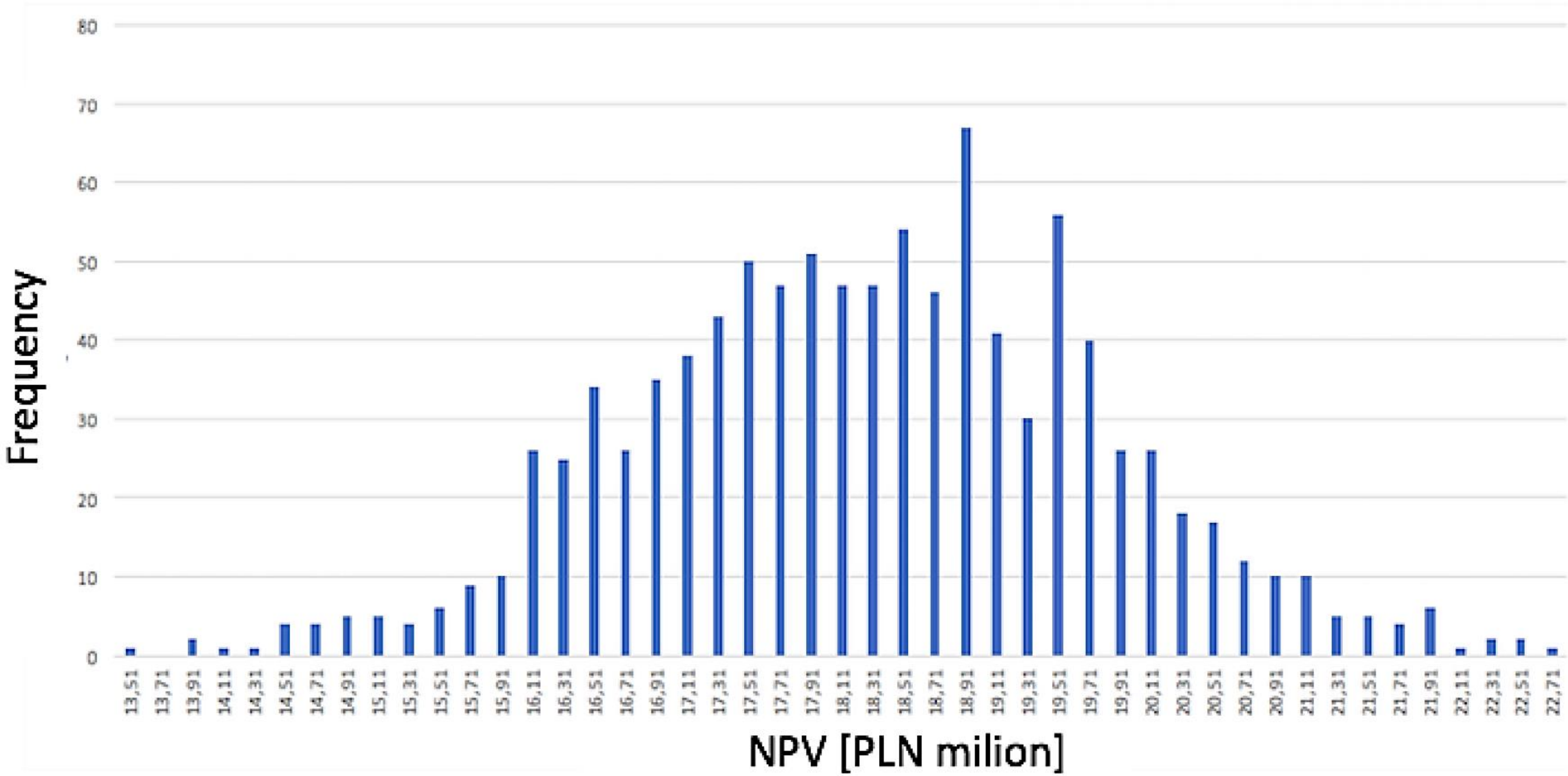


Fig. 5. The histogram of the frequency of specific ranges of NPV values

TABLE 2. Monte Carlo simulation results [PLN]

TABELA 2. Wyniki symulacji Monte Carlo [zł]

The average NPV	18,193,050.6
The standard deviation of NPV	1,491,947.6
The standard error of average NPV	47,179.5
NPV median	18,217,334.4
Skewness	–0.020
Range	9,201,124.1
Minimum	13,488,995.3
Maximum	22,690,119.4

TABLE 3. Results of VaR calculations

TABELA 3. Wyniki obliczeń VaR

Average NPV (PLN)	18,193,050.6
The standard deviation of NPV (PLN)	1,491,947.6
The confidence level	0.95
VaR (PLN)	2,454,035.4

Conclusions on agricultural biogas plant:

- Negative financial result is unlikely
- Investment risk is low