NAZARBAYEV UNIVERSITY
SCHOOL OF ENGINEERING

International Seminar on:
"Towards Smart Sustainable Cities – Integrated Approaches"
June 15-16, 2017. Astana-Kazakhstan

Technical and Economic Assessment of Clean Energy Technologies

Presenter:

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Astana, 15-16 June 2017

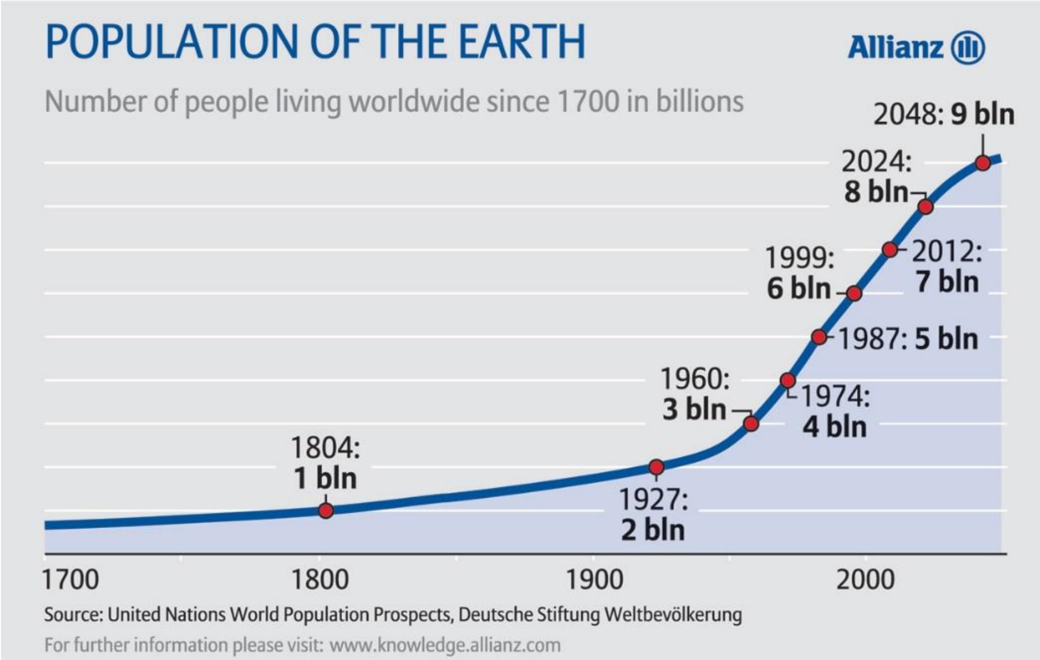
OUTLINE

1. Introduction World Energy Demand and Challenges.
2. Clean Energy Technologies (CET).
3. Introduction to CET Assessment (e.g. RETScreen).
4. Example of Case Studies across Kazakhstan.
5. Q & A’s

1. Introduction to World Energy Demand and Challenges

- **World population(1):**
  - 2500 Millions in 1950
  - **7000 Millions in 2011**
  - Projection: 8000/9000 Millions in 2025/2050

- World population **growth rate** is decaying, but still positive and larger in less developed countries(1).

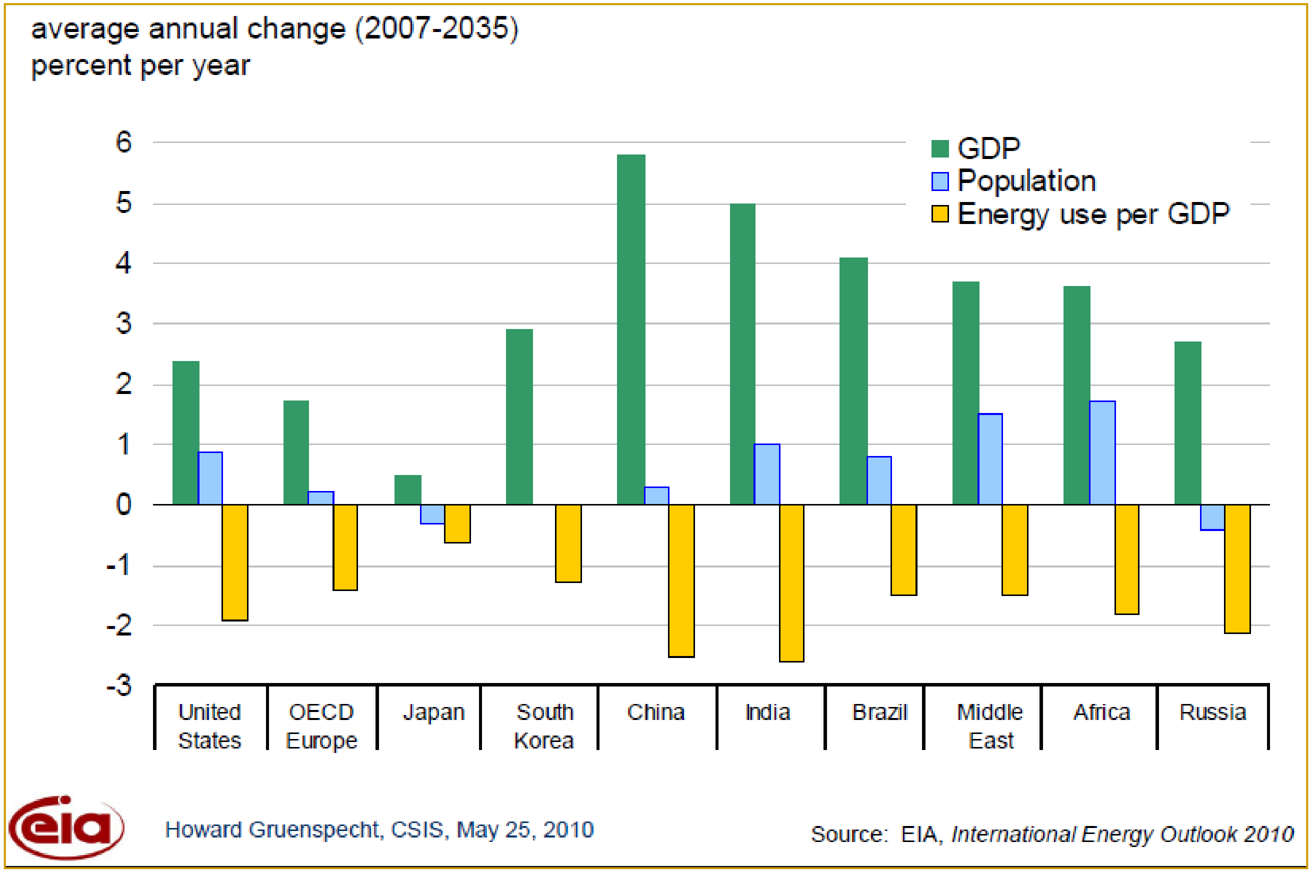


http://www.historyfuturenow.com/wp/wp-content/uploads/2012/11/populationgrowthhistory2.jpg

Source: (1) UN

Economy and population drive increase in energy demand

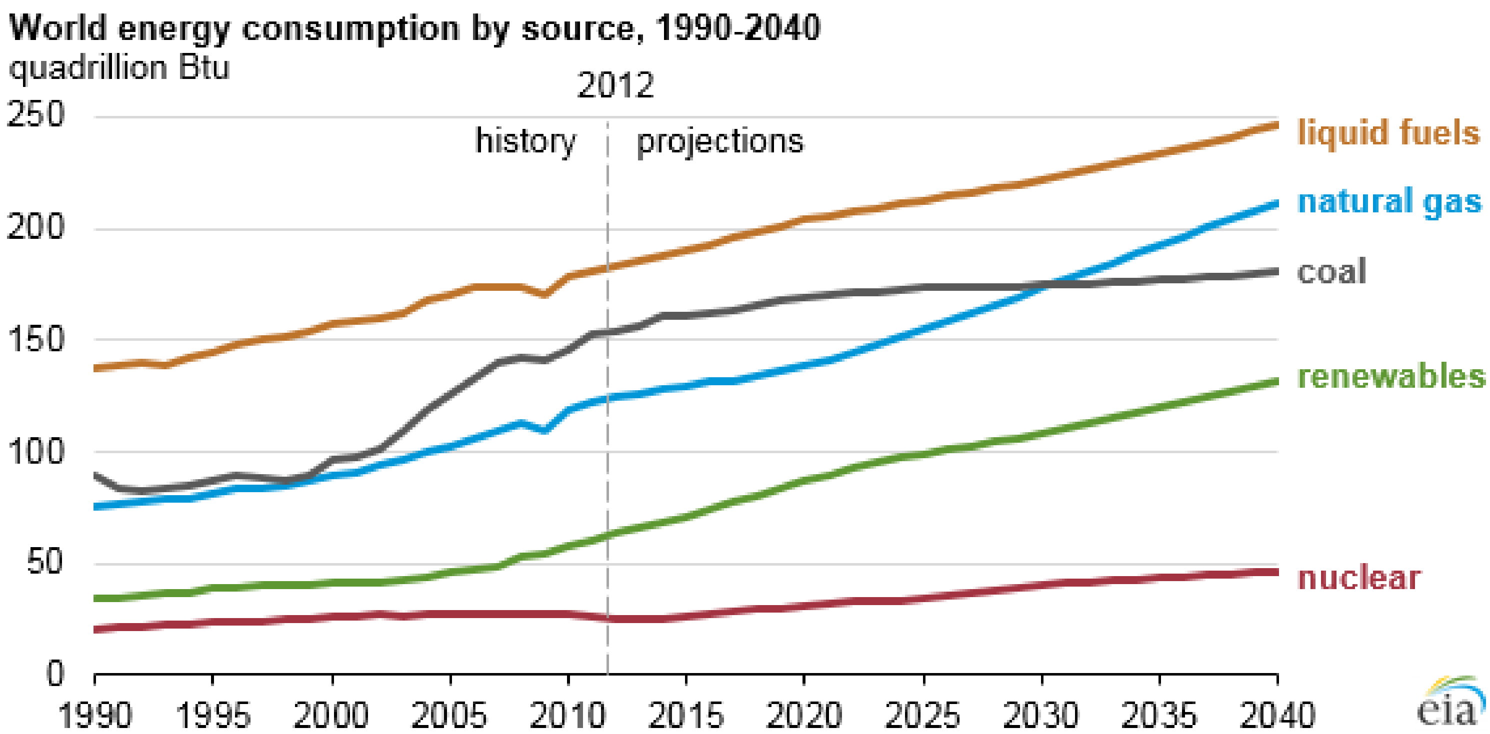
China and India with largest projected average annual growth (>5%) 2007/2035[1].



Source: (1) International Energy Outlook 2010, with Proyections to 2035 by Howard Gruenspecht, Deputy Administrator of US-EIA. *csis.org/files/attachments/100525_HGruenspecht_IEO2010.pdf*

Projected Global Growth in Energy Demand

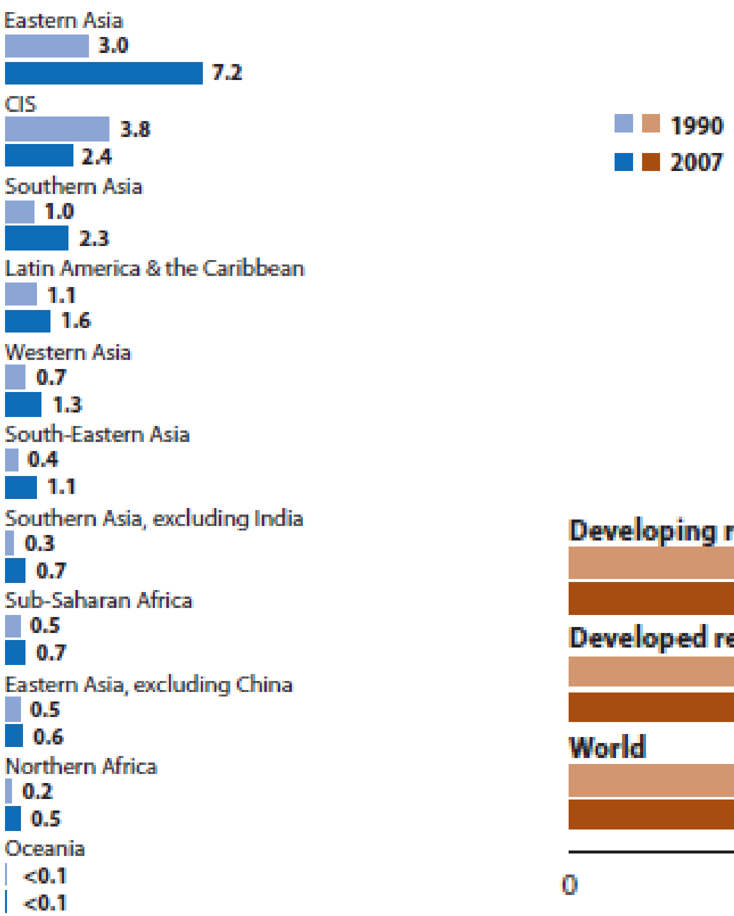
- **48%** of total energy consumption increase expected (2012-40).
- **Renewable** (exc. biofuels) (2.6%/year) is the **fastest growing** source (2012-40).
- **Natural gas** is the fastest growing fossil fuel (1.9%/year) (2012-40).

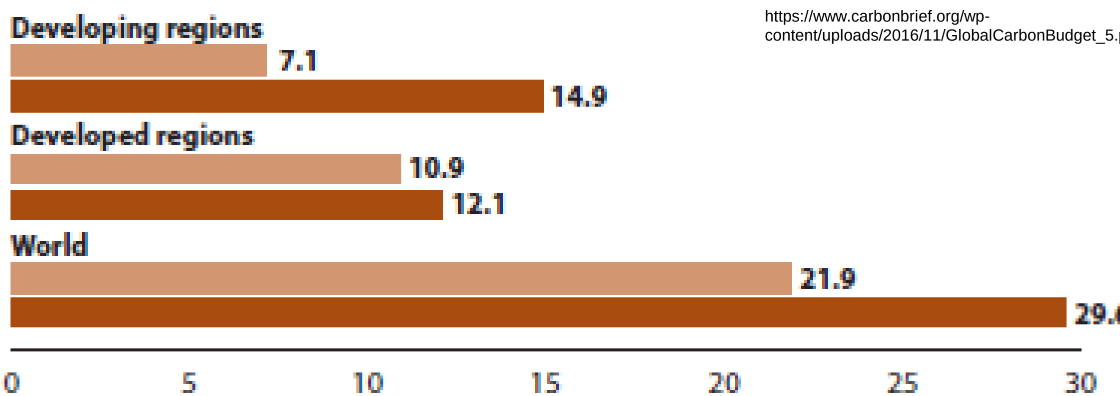


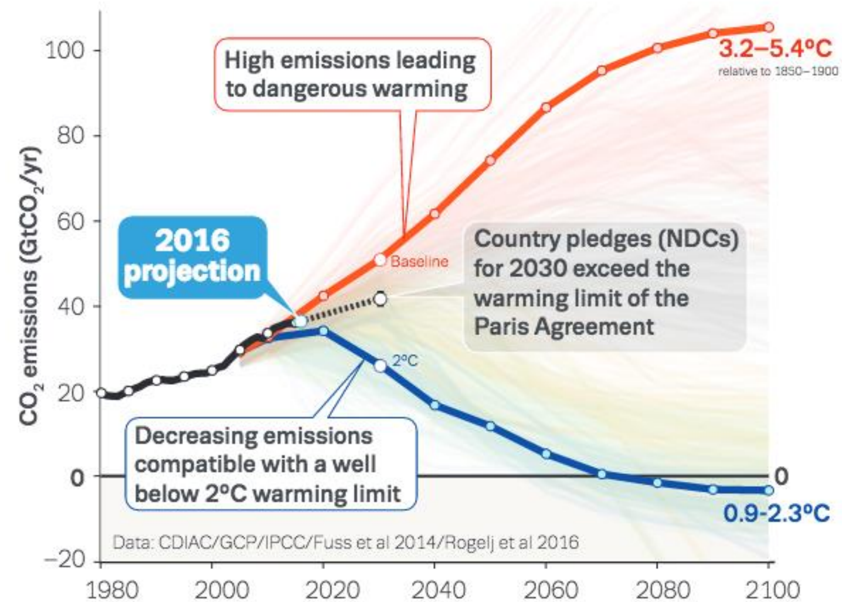
https://www.eia.gov/todayinenergy/detail.php?id=26212

What happens with CO2 emissions?

Emissions of carbon dioxide (CO_2), 1990 and 2007
(Billions of metric tons)







https://www.carbonbrief.org/wp-content/uploads/2016/11/GlobalCarbonBudget_5.png

CIS: Commonwealth of Independent Countries (Fromer Soviet Union countries)

Source: The Millennium Development Goals Report, UN, 2010

*Furthermore, **today**:*

- 1100 millions (18%) lack access to drinking water*
- 2600 millions (42%) lack good sanitary services*
- 1300 millions (20%) lack of electricity**
- 2700 millions (40%) rely on biomass for cooking**
- Irreversible climate change

Then, we have to face creatively the Energy issues in today´s world!!

➔ ***Clean Energy Technologies***

Picture: http://www.antemedius.com/content/climate-change-effects-hugely-unequal-globally

Picture: http://www.aboutmyplanet.com/files/2009/03/climate-change_1.jpg

Sources: (*) WHO/UNICEF, 2005 : 40; (**) IEA: World Energy Outlook 2011(most stats based on 2009 data)

2. Clean Energy Technologies

Clean Energy Technologies

Pursue the reduction of ecological footprint & pollution vs. conventional technologies

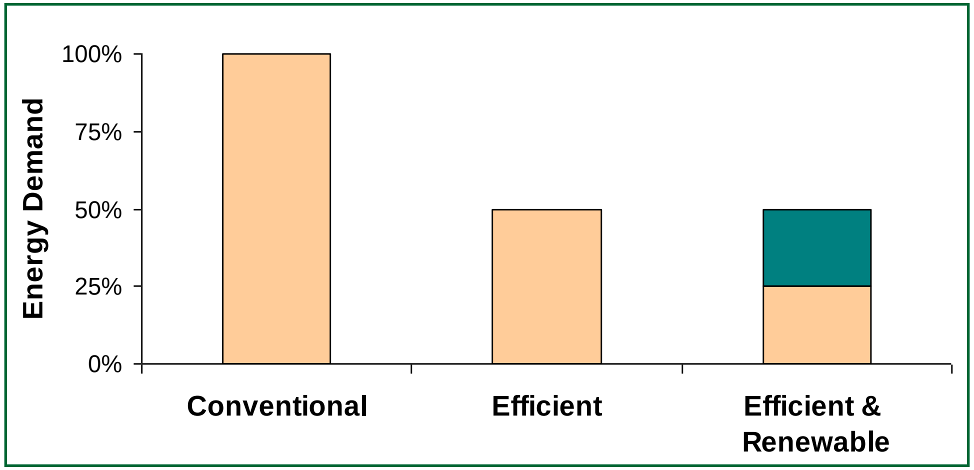
Energy Efficiency

- Using less energy resources to meet the same energy needs

Renewable Energy

- Using non-depleting natural resources to meet energy needs

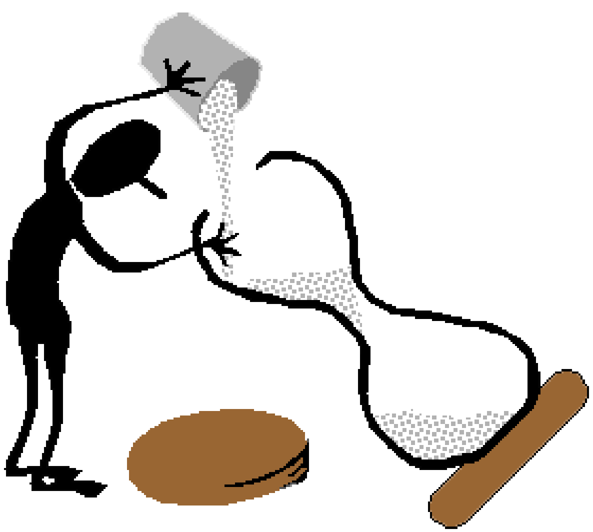
Super Insulated Passive Solar Home



Major Barrier to Clean Energy Technologies

- **False Paradigm: Total cost =** purchase cost

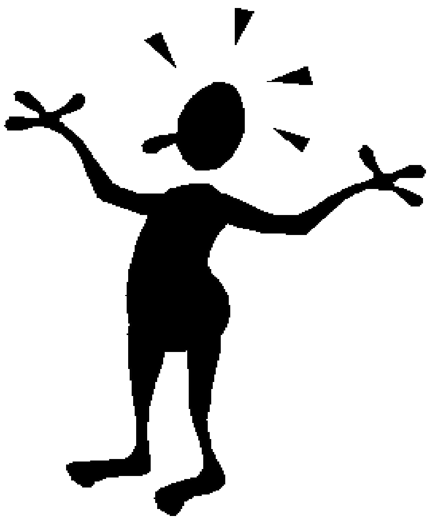
- **Reality: Total cost =** purchase cost



+ *annual fuel and O&M costs*
+ *major overhaul costs*
+ *decommissioning costs*
+ *financing costs*
+ *etc.*

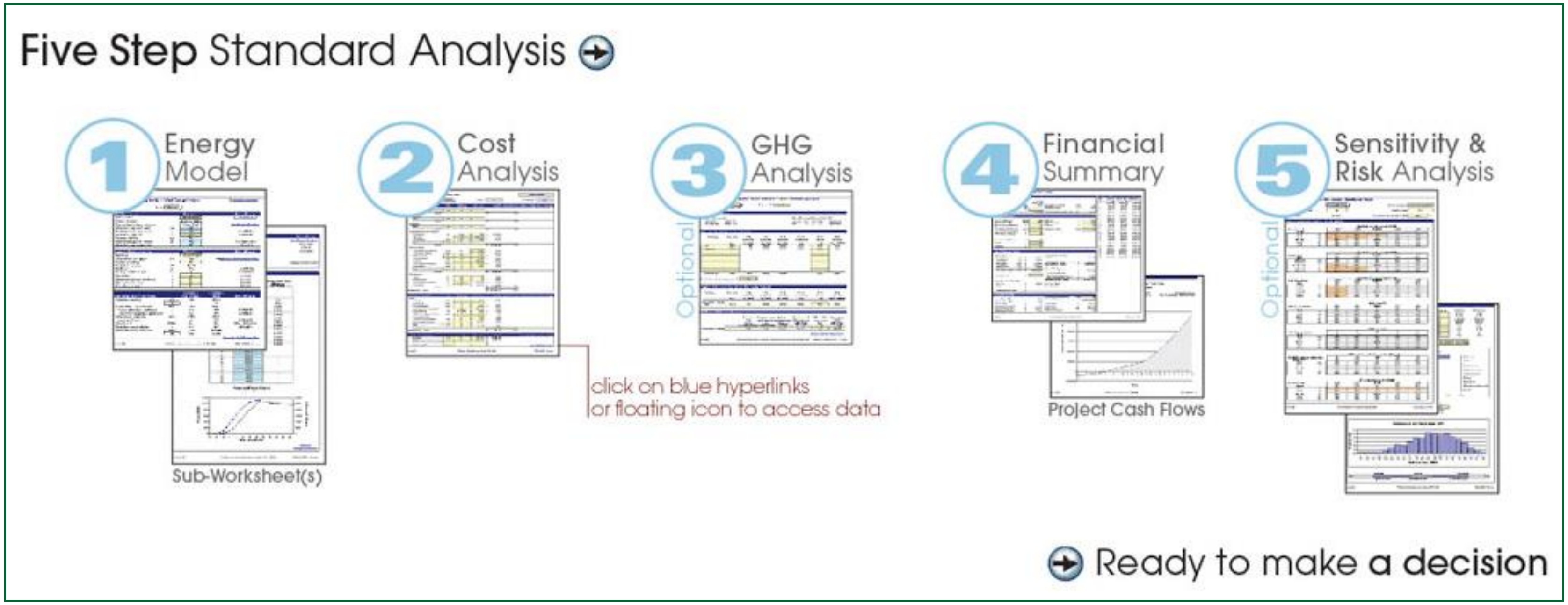
Common Facts about Clean Energy Technologies

- Relative to conventional technologies:
  - Typically higher initial costs
  - Generally lower operating costs
  - Environmentally cleaner
  - Favor generation of local jobs
  - Often cost effective on life-cycle cost basis ➔



Life Cycle Cost and GHG Analysis

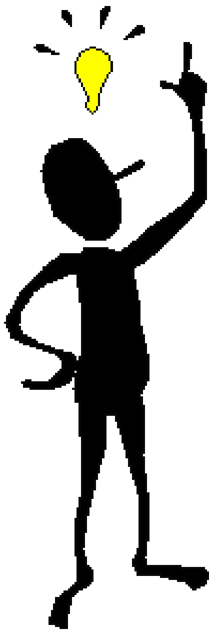
3. Introduction to CET Assessment (e.g. RETScreen) (Life Cycle Cost and GHG Analysis)



Canada

RETScreen® Approach ➡ Life Cycle Cost Analysis

- Comparison between a **"base case"** —typically the conventional technology or measure—and a **"proposed case"**—the clean energy technology.
- Cost analysis based on **incremental values**.
- Energy benefits are the same for base and proposed case. Thus, X units of energy produced by proposed technology are compared to X units of energy from base case.
- End goal is to determine whether or not the **balance of costs** of the proposed technology is attractive **along the life-cycle of the project**.



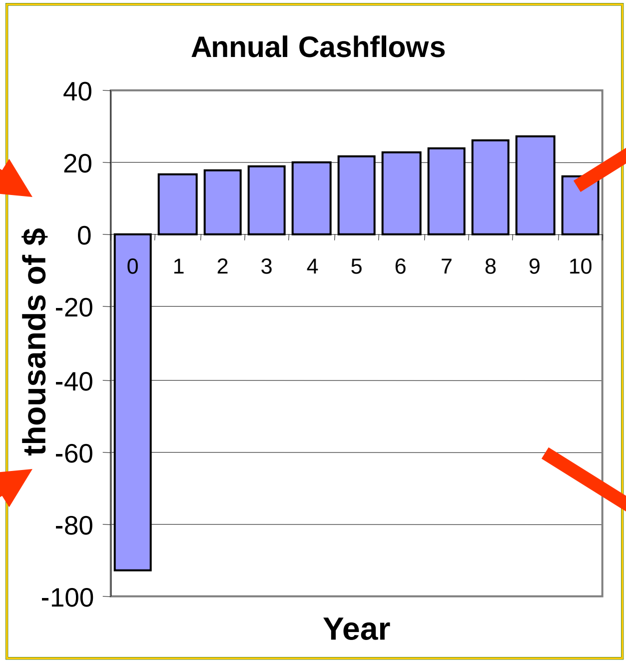
Life Cycle Cost Analysis: How does it work in RETScreen®?

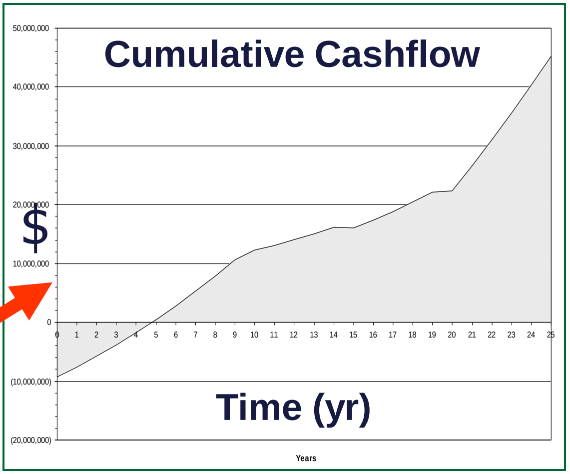
Cash Inflows

Fuel Savings
O&M Savings
Periodic Savings
Incentives
Production Credits
GHG Credits

Cash Outflows

Equity Investment
Annual Debt Payments
O&M Payments
Periodic Costs





Indicators

Net Present Value
Simple Payback
IRR
Debt Service Coverage
Etc.

4. Example of Case Studies across Kazakhstan

http://www.virtualsources.com/Countries/Asia%20Countries/kz-map.gif

What are current Energy Sources in Kazakhstan?

- Installed capacity of power plants: **19.8 GW @ 1-1-2012**
-
- **Power generation (2011)**: 81.8 TWh
  - **89% fossil fuel**.
  - **10% hydro**.
  - 1% other renewables.
  - **6.7 GW of power generation is associated to CHP**.
  - **70% of Thermal Power Plants use Coal**.

- Total Primary Energy Supply (TPES) @ 2009:
  - **Coal: 47.9 %**
  - Gas: 29.1 %
  - Oil: 21.8 %
  - Hydro: 0.9 %
  - Other renewables (biomass included): 0.2%

source: http://www.reegle.info/policy-and-regulatory-overviews/KZ **Based on REEEP Policy Database**

Kazakhstan Renewable Energy: Executive Summary

- About **50%** of **Kazakhstan** territory has average wind speed of **4-5 m/s @ 30m** above the ground. Country wide-wind atlas is available.
- In **May 2013, terms of agreement** was signed with Eurasian Development Bank to build a **45 MW wind farm facility in Akmola**. Three more wind farms will be launched in Almaty between 2014-2018. **First wind farm** was launched in **Zhambyl with capacity of 1.5MW**.
- **Hydropower** accounts for **10-12%** of generation capacity. Kazakhstan is in **3rd place** in **potential** hydro within **CIS countries**.
- **Solar irradiation** of **1300-1800 kWh/m²/year**. However, very little use of this resource yet. Nevertheless, **6 x 50MW solar** plants will be built in southern **Zhambyl** by end of **2016**.
- 19.8 GW installed Capacity for Power Generation. **6.7 GW is currently in CHP** configuration. 89% of Fossil Fuel and 70% is Coal.
- **Large resources** of middle and low temperature **thermal water**.
- FIT and favorable policies in place (e.g., DAMU fund)

source: http://www.reegle.info/policy-and-regulatory-overviews/KZ Based on REEEP Policy Database

4.1. TECHNICAL AND ECONOMIC PREFEASIBILITY ANALYSIS OF RESIDENTAL SOLAR PV SYSTEM IN SOUTH KAZAKHSTAN

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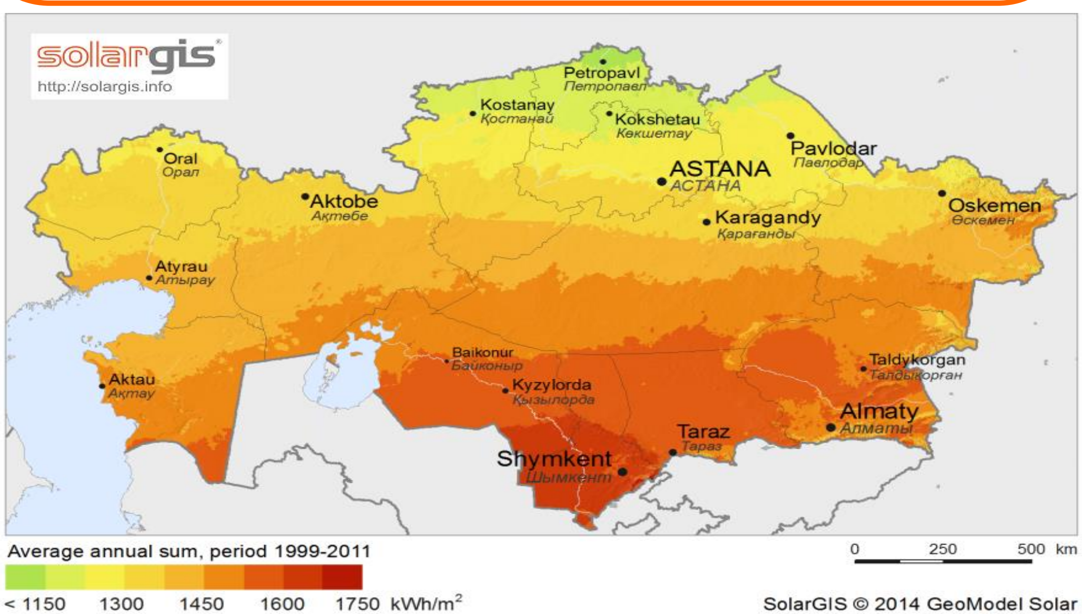
Solar radiation on the territory of Kazakhstan



Results for LCCA

Economic indicators for 6.6 - kW solar PV system for 3 locations in South-Kazakhstan.

Financial Results	Shymkent	Kyzyl-orda	Taraz
IRR on Equity	17.9%	17.3%	16%
Net Annual Income	$1191	$1078	$973
Net Present Value	$14523	$13 741	$11366
Payback Period	9.9	10.2	10.8
Benefit-Cost Ratio	9.65	9.03	7.84

Discussion of Results for LCCA (cont´d)

Extra Governmental support

↓

“DAMU” Entrepreneurship Development Fund”

↓

Compensating 7% of Debt Interest Rate

DAMU

Source: http://www.nationalbank.kz/?docid=158&switch=english

Results for LCCA (cont´d)

Effect on financial viability by using DAMU fund

Financial Results	Residential PV in Shymkent (no DAMU)	Residential PV in Shymkent with DAMU subsidy
IRR on equity	17.9	18.1
Net Annual Income	$1191	$2523
Net Present Value	$14523	$26220
Payback Period	9.9	5.5
Benefit-Cost Ratio	9.65	4.12

Concluding Remarks

- There is good economic potential of solar on-grid PV system in South Kazakhstan, using local manufacturer.

- The analysis determined that a 6.6 kWp PV array may generate and export to the grid a minimum of 8,1 MWh/year in Taraz, and a maximum of 8.9 MWh/year in Shymkent.

- A new policy to reduce debt interest rate, in conjunction with Feed-in Tariff (FIT) is encouraged from the study.

4.2. Biogas from Animal Waste. Case Study: Prefeasibility of Biogas to Power & Heating at Buranbayev Farm, Uralsk-Kazakhstan

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Co-Authors:

Madina Bekbauova **(National Centre of Science and Technology Evaluation)**

Daniyar Seitenov **(Dept. of Electrical and Electronic Eng., Nazarbayev University)**

Jong Kim **(Dept. of Civil Engineering, Nazarbayev University)**

Andrei Dobrita **(Renewable Energy Consultant, Kazakhstan)**

Project Technical Rationale

Farm animals

Manure collection

Biogas plant

Heat

Biogas

Fertilizers

Electricity to grid

CHP

Feed-in-Tariff Income

Price of electricity exported to grid (Feed-in-tariff: FIT)*	KZT/MWh	32 230
Annual Electricity Generation	MWh	801
Annual FIT income (escalated with inflation rate)	**KZT**	**25 830 953**

Note: According to new Policies adopted by Government of Kazakhstan, 2014, KEGOC (Kazakhstan Electricity Grid Operating Company will purchase the electricity)

Damu Entrepreneurship Development Fund

1

Entrepreneur applies to the bank/leasing company for a loan / lease

2

The Bank/Leasing company evaluates the project for the granting of loan/lease

3

Entrepreneur, having obtained approval of the bank/leasing company sends the loan documents to akimat (city hall, Local/Regional program coordinator)

4

Local/Regional Coordinator shall present the subsidization issue of to the Regional Coordinating Council (RCC)

5

RCC gives an approval and sends it to the bank/leasing company and to "Damu" Fund

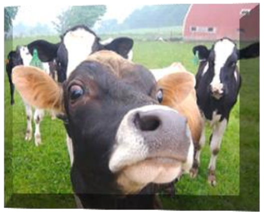
6

Bank/leasing company enters into a tripartite agreement with the entrepreneur and "Damu" Fund

7

On the basis of the agreement "Damu" Fund transfers to the bank/leasing company the subsidized part of the interest rate on the entrepreneur's loan/lease

Project Energetic Outcome



625 heads of animals

Manure collection

Biogas plant

Heat

Biogas 316 905 std-m^3/year

Fertilizers

Electricity
801 MWh/year

CHP

Concluding Remarks

- ✓ Environmental, Legal, Technical and Economic conditions are aligned in Kazakhstan towards good feasibility of CET projects.
- ✓ FIT, CAPEX subsidies are key elements in feasibility of these projects.
- ✓ Significant opportunities for reduction of CO_2 emissions.
- ✓ Hence, Feasibility Analysis (LCCA) must be taught and promoted in all disciplines in order to promote investment in this sector.

Thanks for your attention!!

http://www.wxdude.com/resources/questions.jpg

4. Wind Energy Project Analysis. Case Study: Wind Farm in Astana.

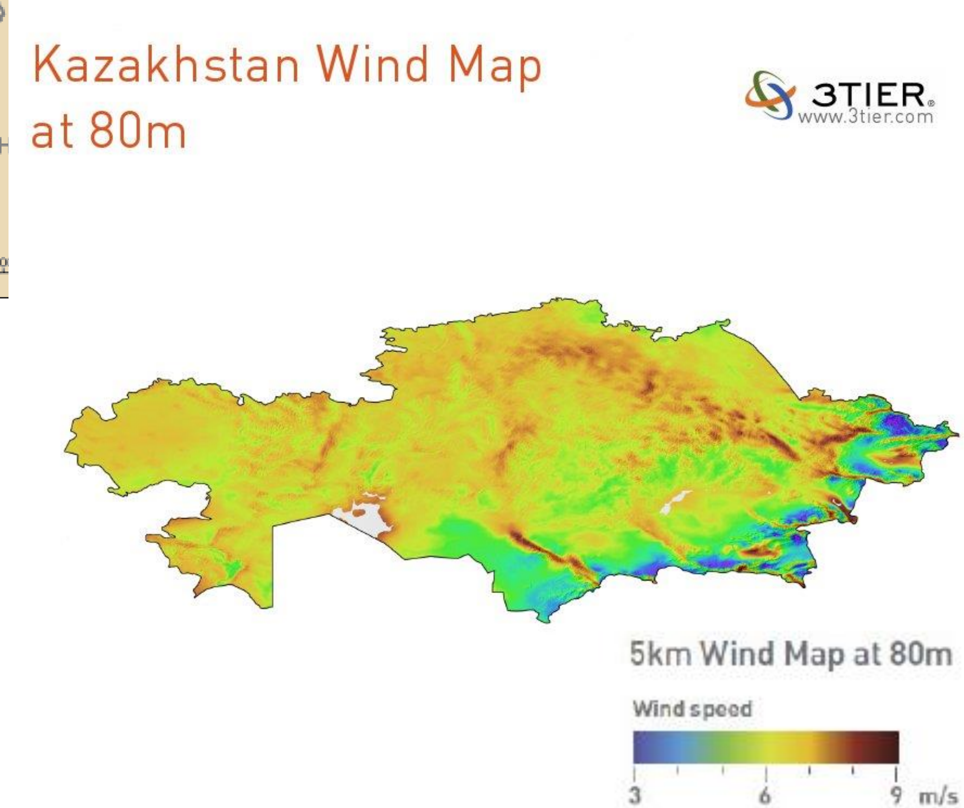
Photo Credit: Nordex AG

Case Study: Wind Farm in Astana, Kazakhstan

Luis R. Rojas-Solórzano, Ph.D.

http://www.virtualsources.com/Countries/Asia%20Countries/kz-map.gif

https://lh3.googleusercontent.com/u-BZSS5vTbwwkPG_vkW2LY2TggZUDK1IQquSeKSVCxJlFgiu5SyBRlYzE-k2q81W_e0fEFuuFBrAmCB8P1bFcnbuuiB6ztxZdK_Ds7KpGrNm4_wp7dA

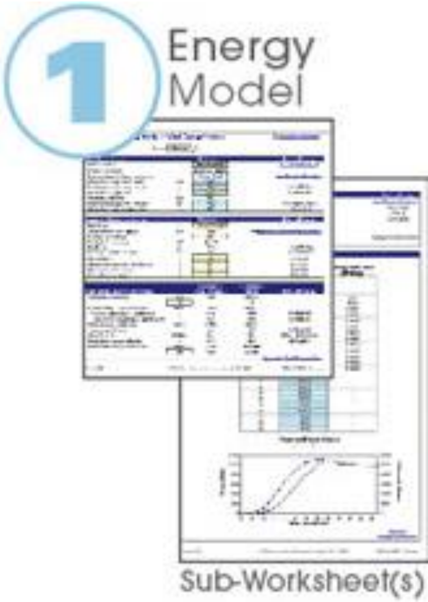


Is it feasible to install a **37.5 MW Wind Farm** in Astana, using Vestas NM72C turbines?

RETScreen® Software Structure
Energy Model:

Fig. 1-14 Photograph of the Astana monitoring tower facing south east (taken by PB staff during tower installation)

- Monitoring tower with **anemometers at: 22 m, 49 m and 51.4 m AGL.**
- **1 year-track** (2006-07)
- Site at **5 km from city** edge, South old city.



http://www.windenergy.kz/files/1215767950_file.pdf

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RETScreen® Software Structure
Energy Model:

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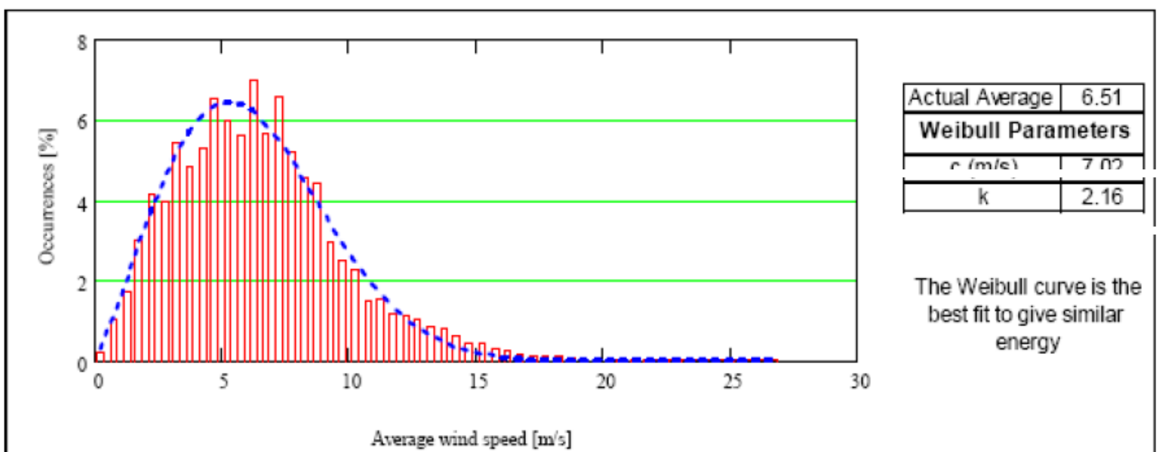
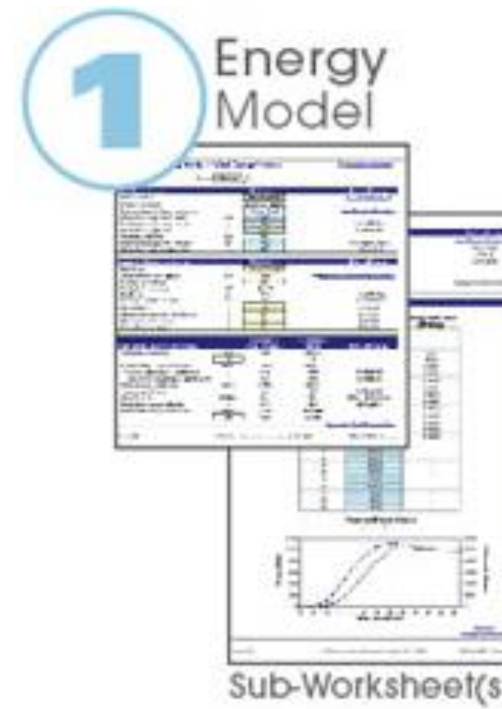
Table 1-10 Wind data statistics for the Astana monitoring tower

Recording Period	Date	Time
Start	2006/10/20	12:50
Finish	2007/10/24	11:50

Wind Statistics	Level 1	Level 2	Level 3
Height above ground level (m)	**51.2**	**49.0**	**22.0**
Minimum wind speed (m/s)	0.2	0.2	0.2
Average wind speed (m/s)	**6.51**	**6.48**	**5.39**
Maximum wind speed (m/s)	26.6	26.7	24.3



The Fig. 1-17 Wind speed distribution and Weibull parameters at 51 m for the Astana monitoring tower



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Energy Model:

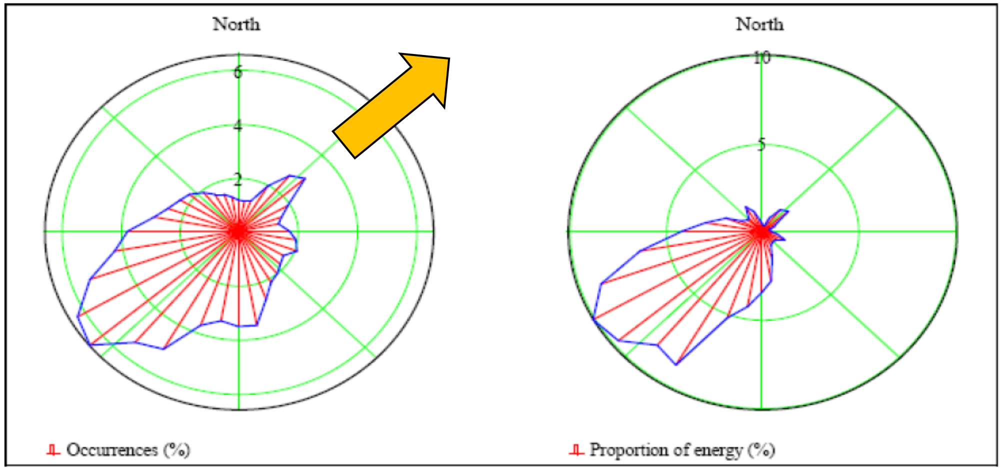
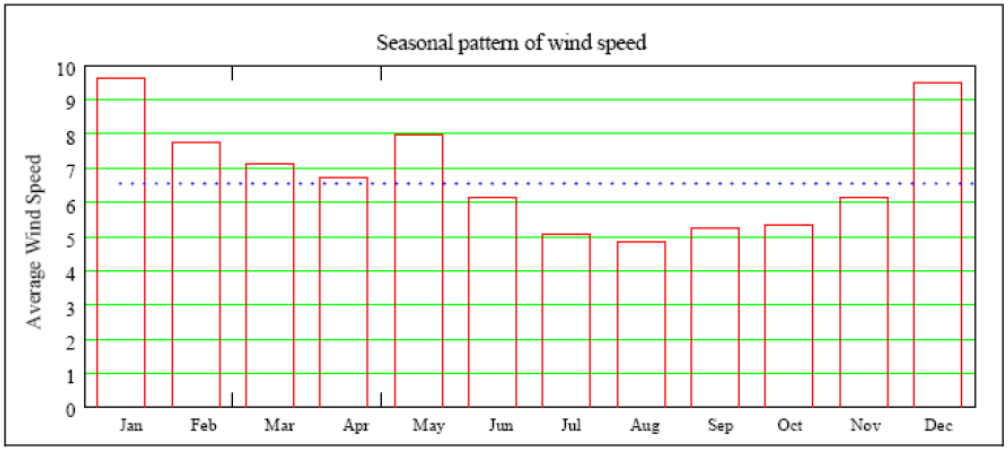
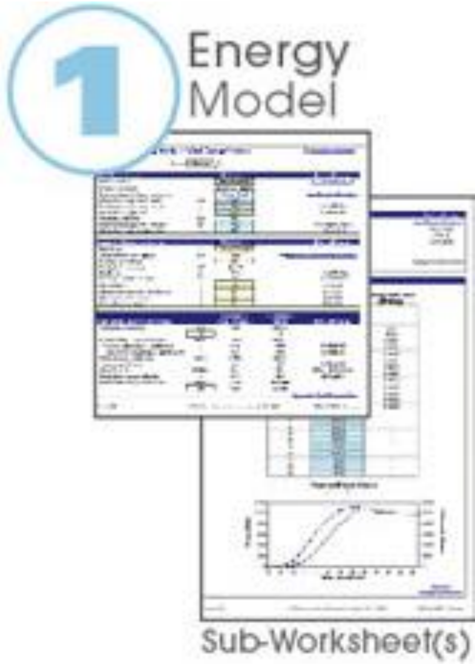


Fig.1-18 Wind direction (left) and energy distributions (right) at 51 m for the Astana monitoring tower



The Figure 1-19 Monthly average wind speeds for the 50 m level



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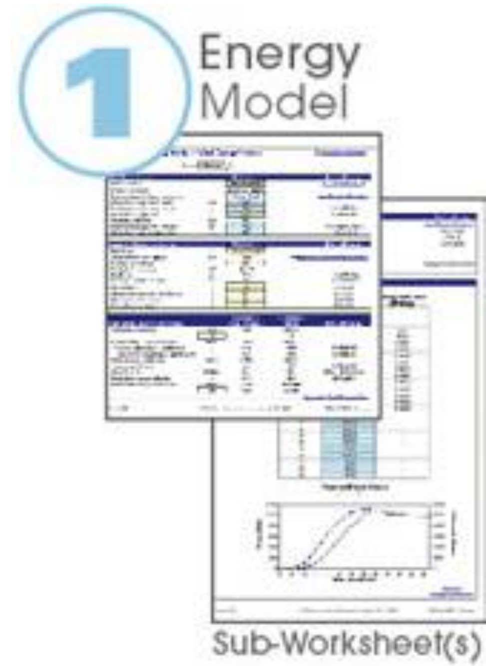
RETScreen® Software Structure
Energy Model:

Technical Assessment Data:

- **25 Vestas 72NC** turbines at 80 m AGL
- Terrain data: **roughness of 0.03m** in 10m contour lines ⇨ **Wind Shear Exp. = 0.13**
- **Airfoil losses (icing) : 2%**
- **Miscelaneous losses** (on-site electrical and degradation) : **7%**
- **Availability : 97%**
- **FIT : 0.182 €/kWh**



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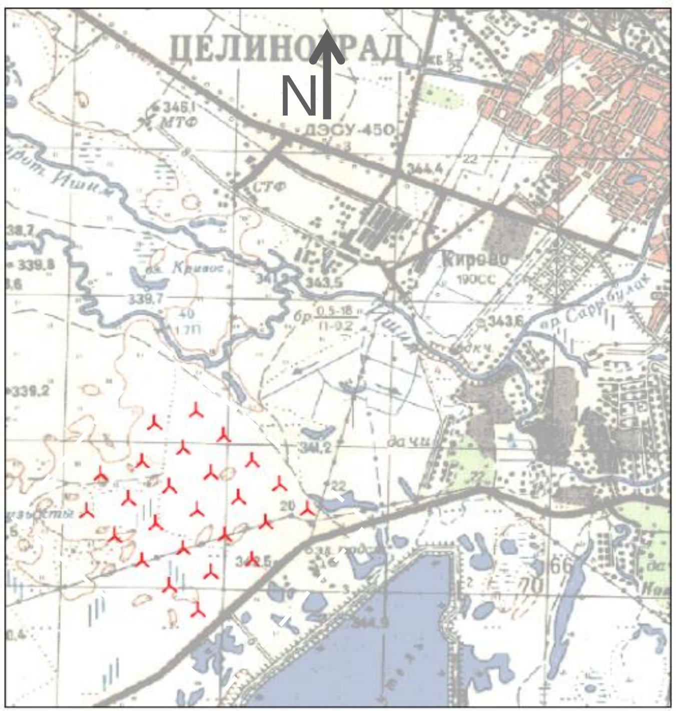
RETScreen® Software Structure
Energy Model:

Technical Assessment Data:

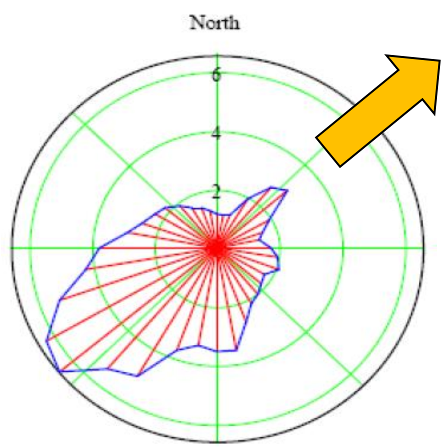
- **5x5 array in S-W**. Airport in S-E with flying path in-out S-W; thus, no interference.



Map of the Astana turbine layout and surrounding area

Array losses: 9%

(wake interference)



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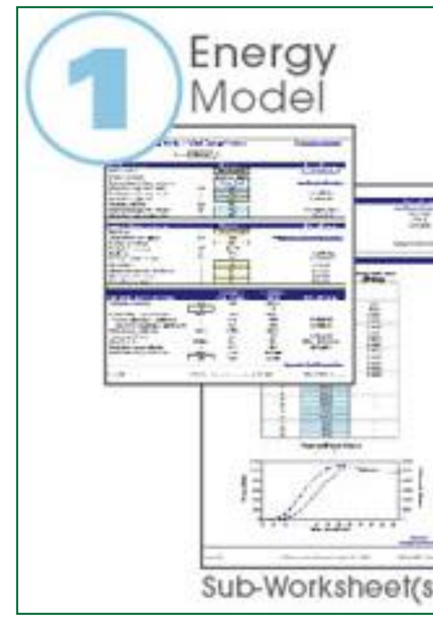


http://www.windenergy.kz/files/1215767950_file.pdf

RETScreen® Software Structure
Cost Analysis:

RETSCREEN® INTERNATIONAL www.retscreen.net

Cost Assessment Data:

- **Capital cost**: **1250 €/kW turbine**, includes installation.
- **O&M: 9 €/MWh**

GHG Emission Reduction Analysis Data:

- **Baseline: Grid** power from Kazakhstan (**89% fossil fuel, 10% hydro and 1% other**)
- **Transmission & Distribution Losses: 7.35%**

http://www.windenergy.kz/files/1215767950_file.pdf

RETScreen® Software Structure Financial Summary:

Financial Input Data:

- Lifetime of project: **20 years**
- Inflation rate: **5 %**
- Discount rate: **9 %**
- Debt ratio: **50%**
- Debt interest rate: **15 %**
- Debt term: **5 years**
- Income taxes: **20 %**
- FIT escalation rate: **8 %**

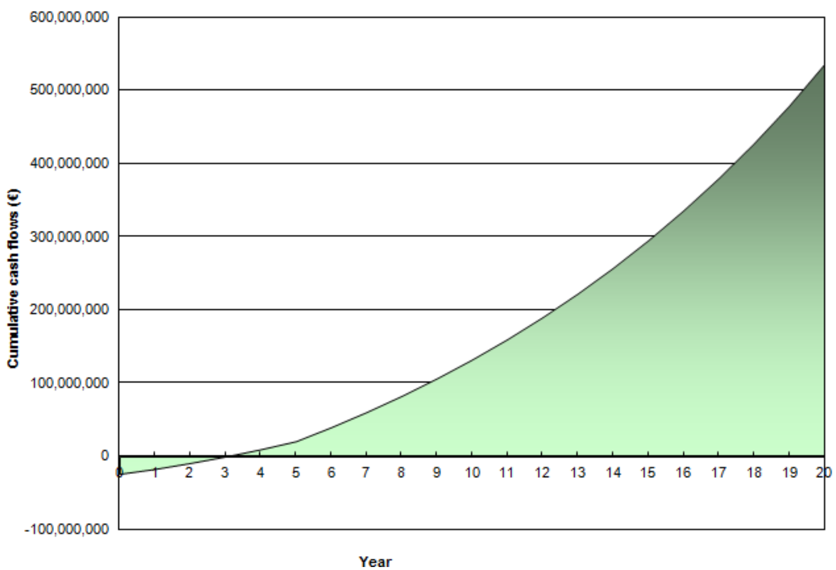
RETScreen® Software Structure
Financial Summary:

RETSCREEN® INTERNATIONAL www.retscreen.net

Financial Output:

Project costs and savings/income summary			
Initial costs			
Power system	100.0%	€	46,875,000
Balance of system & misc.	0.0%	€	0
Total initial costs	**100.0%**	**€**	**46,875,000**
Annual costs and debt payments			
O&M		€	757,035
Fuel cost - proposed case		€	0
Debt payments - 5 yrs		€	6,991,771
Total annual costs		**€**	**7,748,806**
Periodic costs (credits)			
Annual savings and income			
Fuel cost - base case		€	0
Electricity export income		€	15,308,953
Total annual savings and income		**€**	**15,308,953**

Financial viability		
Pre-tax IRR - equity	%	53.0%
Pre-tax IRR - assets	%	32.7%
After-tax IRR - equity	%	44.8%
After-tax IRR - assets	%	28.0%
Simple payback	yr	3.2
Equity payback	yr	3.0
Net Present Value (NPV)	€	169,887,588
Annual life cycle savings	€/yr	18,610,586
Benefit-Cost (B-C) ratio		8.25
Debt service coverage		2.25
Energy production cost	€/MWh	44.34
GHG reduction cost	€/tCO2	(549)



RETScreen® Software Structure Sensitivity and Risk Analysis:

RETSCREEN® INTERNATIONAL www.retscreen.net

RETScreen Sensitivity and Risk Analysis - Power project

☑ Sensitivity analysis

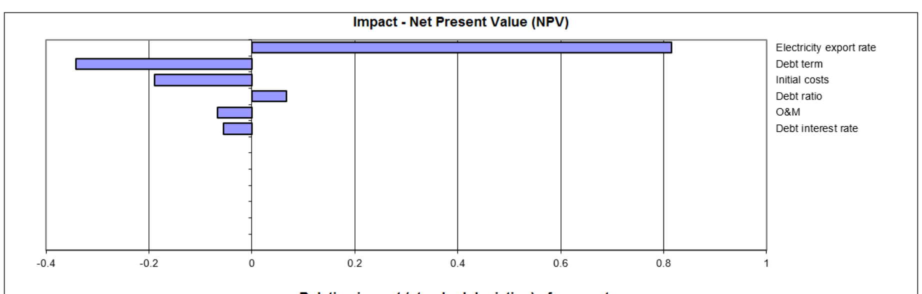
Perform analysis on	Net Present Value (NPV)
Sensitivity range	20%
Threshold	155000000 €

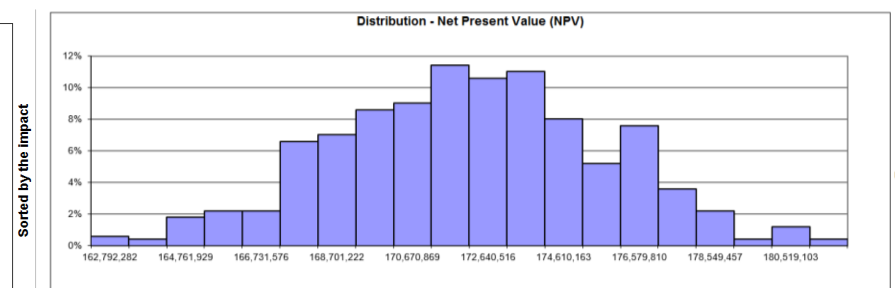
Electricity export rate		Initial costs				€
€/MWh		37,500,000 -20%	42,187,500 -10%	46,875,000 0%	51,562,500 10%	56,250,000 20%
145.60	-20%	134,235,817	129,795,312	125,354,807	120,914,301	116,473,796
163.80	-10%	156,502,208	152,061,703	147,621,197	143,180,692	138,740,187
182.00	0%	178,768,599	174,328,094	**169,887,588**	165,447,083	161,006,578
200.20	10%	201,034,990	196,594,484	192,153,979	187,713,474	183,272,968
218.40	20%	223,301,380	218,860,875	214,420,370	209,979,864	205,539,359

☑ Risk analysis

Perform analysis on: Net Present Value (NPV)

Parameter	Unit	Value	Range (+/-)	Minimum	Maximum
Initial costs	€	46,875,000	5%	44,531,250	49,218,750
O&M	€	757,035	10%	681,332	832,739
Electricity export rate	€/MWh	182.00	4%	174.72	189.28
Debt ratio	%	50%	10%	45%	55%
Debt interest rate	%	15.00%	5%	14.25%	15.75%
Debt term	yr	5	10%	4.5	5.5





In cooperation with the CTI

Energy funding programme
Swiss Competence Centers for Energy Research

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Confederation

Commission for Technology and Innovation CTI

SCCER CREST

CREST - Competence Center for Research in Energy, Society and Transition

The Competence Center for Research in Energy, Society and Transition - CREST - contributes to the energy transition in Switzerland by providing detailed, evidence-based recommendations on policies that help to reduce energy demand, foster innovation, and increase the share of renewables in a cost-efficient way. The center brings together research groups from most major Swiss research institutions and fills important gaps in the research landscape.

SCCER CREST covers four overarching questions:

- Which measures and conditions promote renewables and facilitate their inclusion in the Swiss energy system?
- Which measures and conditions facilitate a substantial reduction of energy consumption?
- What are feasible pathways for the Swiss energy transition?
- Which governance structures are conducive for the energy transition in the Swiss context (legal, social, and political)?

Work Package 1

Energy, Innovation, Management

Addressing the role of firms and regions for the energy transition, including innovation, new business models, investment, regional development, and social acceptance of new technologies.

Work Package 2

Change of Behavior

Addressing the behavior of individuals to provide a better understanding of the decisions of energy consumers, of the determinants of energy consumption, and of options for reducing energy demand.

Work Package 3

Energy Policy, Markets and Regulation

Addressing the energy policy and energy market regulation from a legal, political and economic perspective. Research covers the design and implementation of new policy measures, energy market regulation, the national and international legal context, and simulation-based policy assessment.

Work Package 4

Energy Governance

Addressing legal and political challenges in the governance of the Energy Strategy. Research will provide recommendations for overcoming situations in which the current governance impedes the transformation towards sustainable energy systems and in which more effective policies, regulations, and processes could facilitate the transformation.

Research Partners

University of Basel · Zurich University of Applied Sciences zhaw · Center for Energy Innovation, Governance and Investment (EGI-HSG) Universität St.Gallen · ETH zürich · Université de Genève · unine Université de Neuchâtel · Universität Luzern · EPFL École Polytechnique Fédérale de Lausanne · Hes·so Valais Wallis

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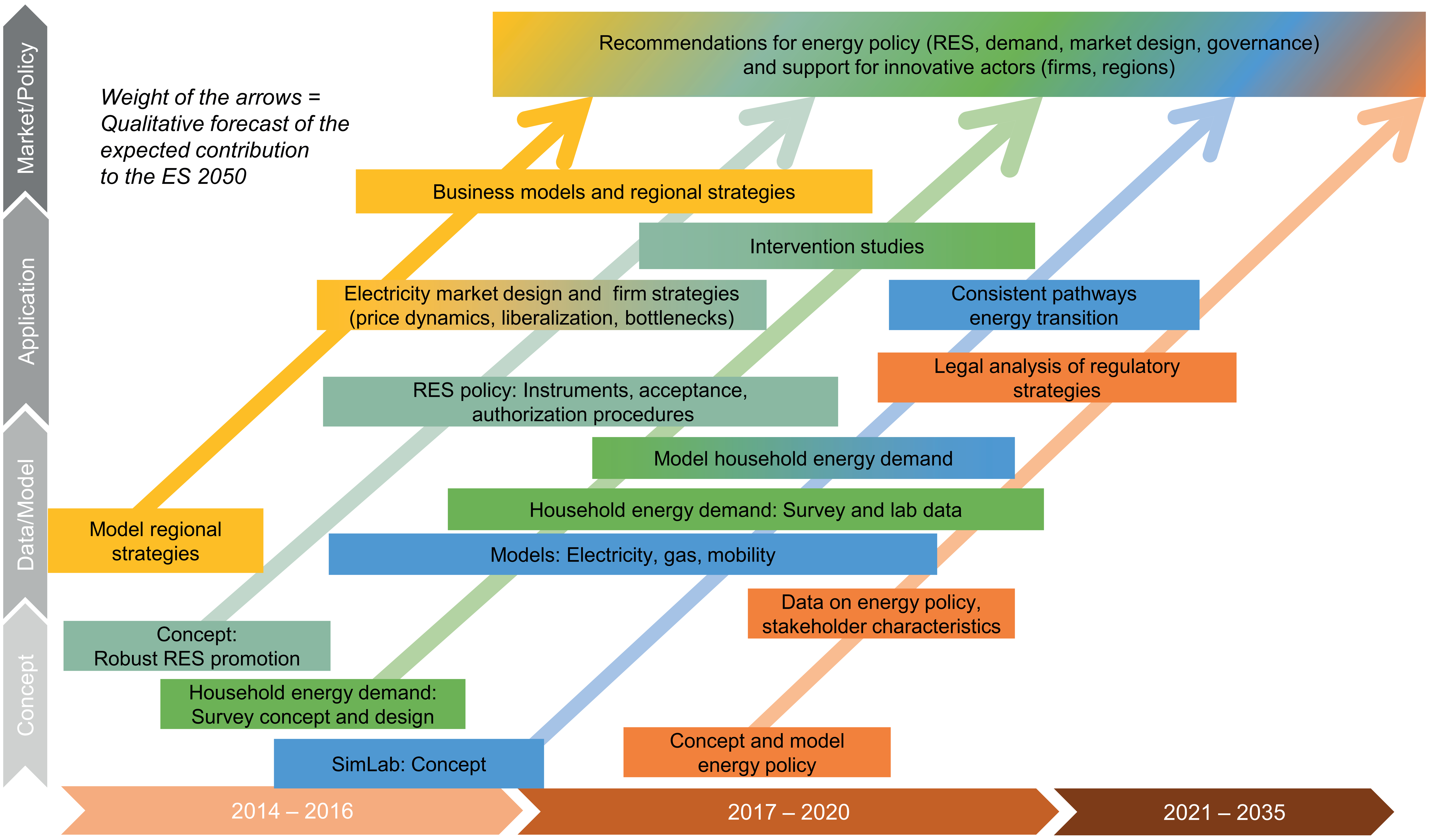
SCCER CREST

Goal/Vision of CREST



SCCER CREST Research Questions:

- Which measures and conditions promote renewables and facilitate their inclusion in the Swiss energy system?
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Zurich University
of Applied Sciences

Smart City Innovation Office in Winterthur, Switzerland

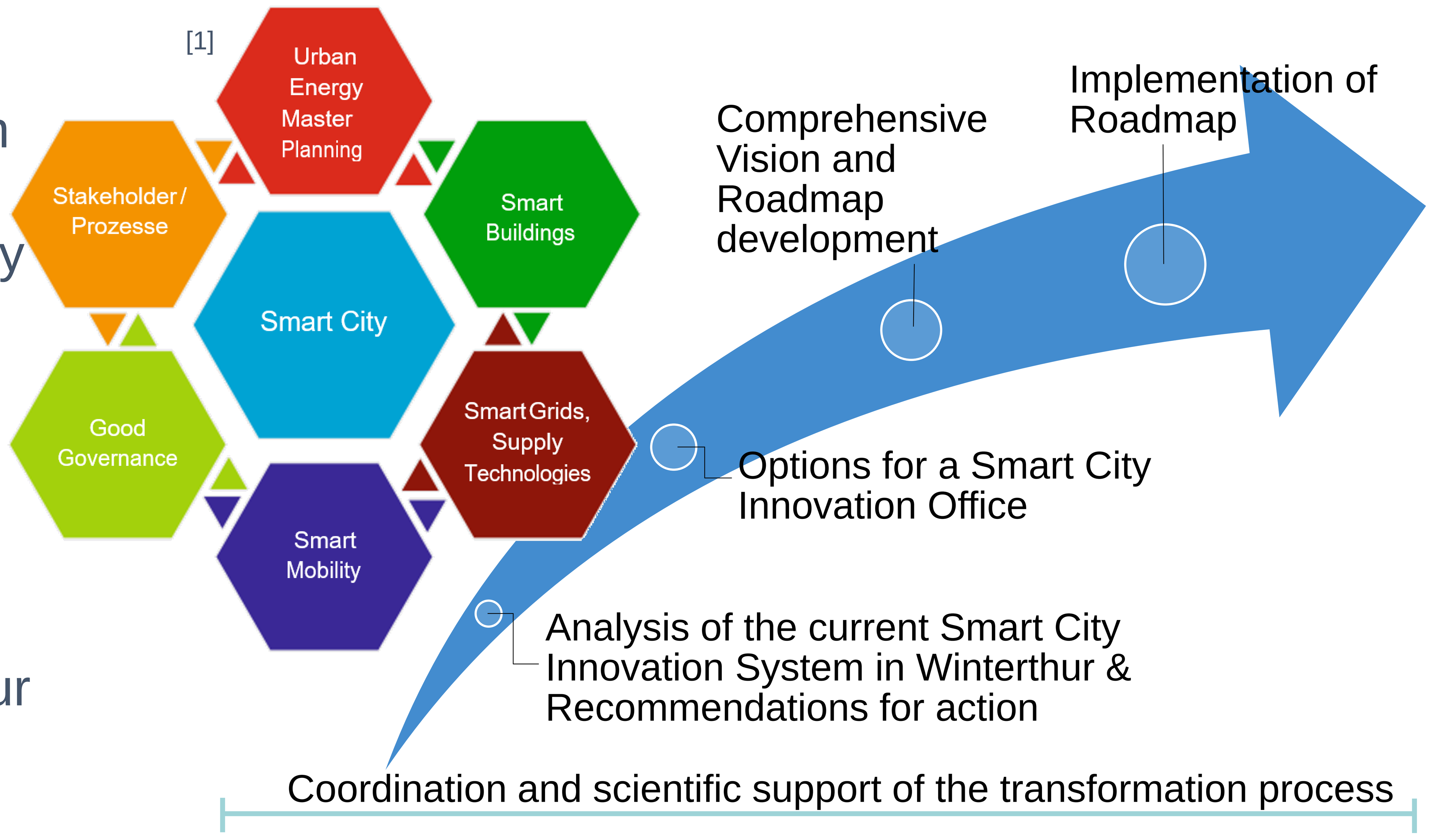
A Research Project funded by the Swiss Federal Office of Energy and the City of Winterthur

Prof. Dr. Bettina Furrer, Dr. Jörg Musiolik, Onur Yildirim, Vicente Carabias

School of Engineering
INE Institute of Sustainable Development
www.zhaw.ch/ine

Goal & Scope

- Design a Smart City Innovation Office as a systemic intermediary in Winterthur
  - In close cooperation with the City of Winterthur and other relevant actors
  - Building upon existing activities and in the respective innovation system
- Coordinate as well as push the transformation process of Winterthur to become a Smart City.

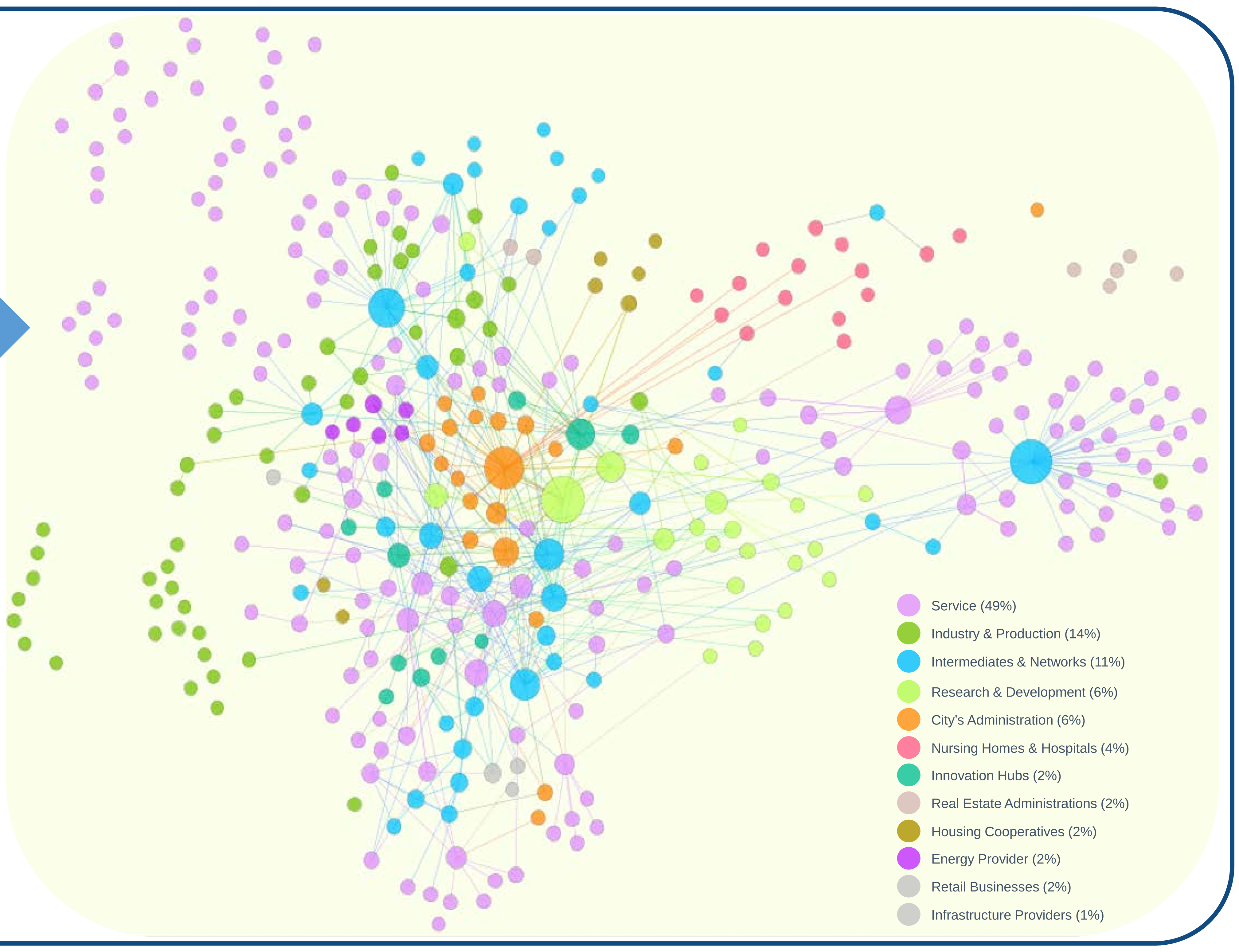


[1] Source: EnergieSchweiz (2015)

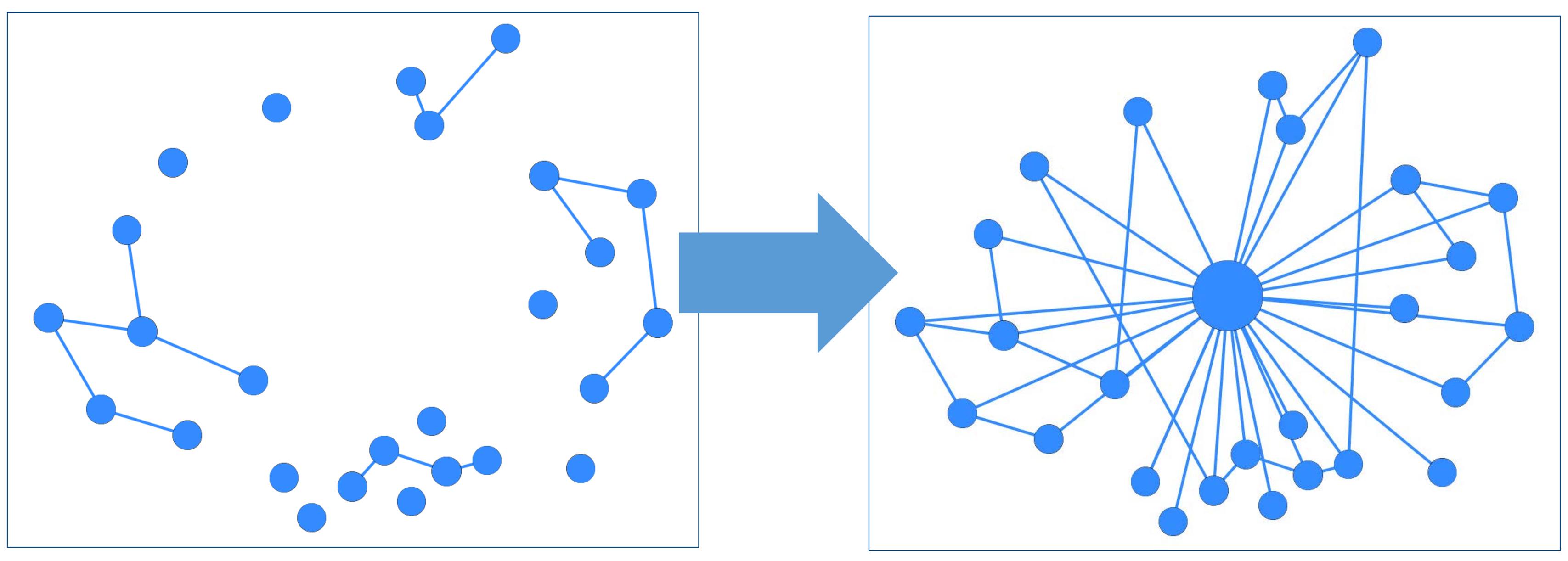
Current State

Analysis of the current system

- Structure (technology, actors, institutions, networks)
- Functions
- Performance
- Phase of development
- Literature research and best practice analysis focussing various Smart City organisation structures



Next Steps



Target state
How can the system be governed? How does it **create added value**?

Transformation process
How can the system be developed towards a defined (political) goal?

- Literature research and best practice analysis (e.g. Smart City Amsterdam)
- Expert interviews
- Development of various options for a Smart City Innovation Office

For more Smart City projects visit the ZHAW's interdisciplinary platform «Smart Cities and Regions».
https://www.zhaw.ch/en/engineering/research/platforms/smart-cities-regions/