American University *of* Armenia

Հայաստանի Ամերիկյան Համալսարան

A US-accredited institution affiliated with the University of California

Current Status of Affairs in the area of Renewable Energy Development in Armenia

Artak Hambarian

Policy Stakeholders Conference

EU-EaP STI cooperation in addressing Energy

12-13 October 2015, Minsk, Belarus

Abstract

- *It has been 4 years since the bringing into of existence of the first Renewable Energy Development Roadmap of Armenia (REDRA) in 2011. The paper addresses the further status of affairs and performs analysis of possible development paths both for domestic use as well as from the point of view of creation of proper infrastructure aiming to support development and export of high value added RE products and services. For domestic use and export of power the following is considered – area needed, resources needed, seasonality issues, related policies, etc. RE as an important direction for economic development is considered. Criteria, such as the growth potential worldwide, existence of cadre, networking and synergistic opportunities, education system, entrepreneurship environment including funding are in the focus.*

Main Total primary energy supply (TPES) Indicators
(as of 31.12.2012)

1000 ktoe

Production	0.38
Energy import	3.20
Energy export	-0.11
Total Primary Energy Supply	3.47
TPES per capita (toe/cap.)	1.15

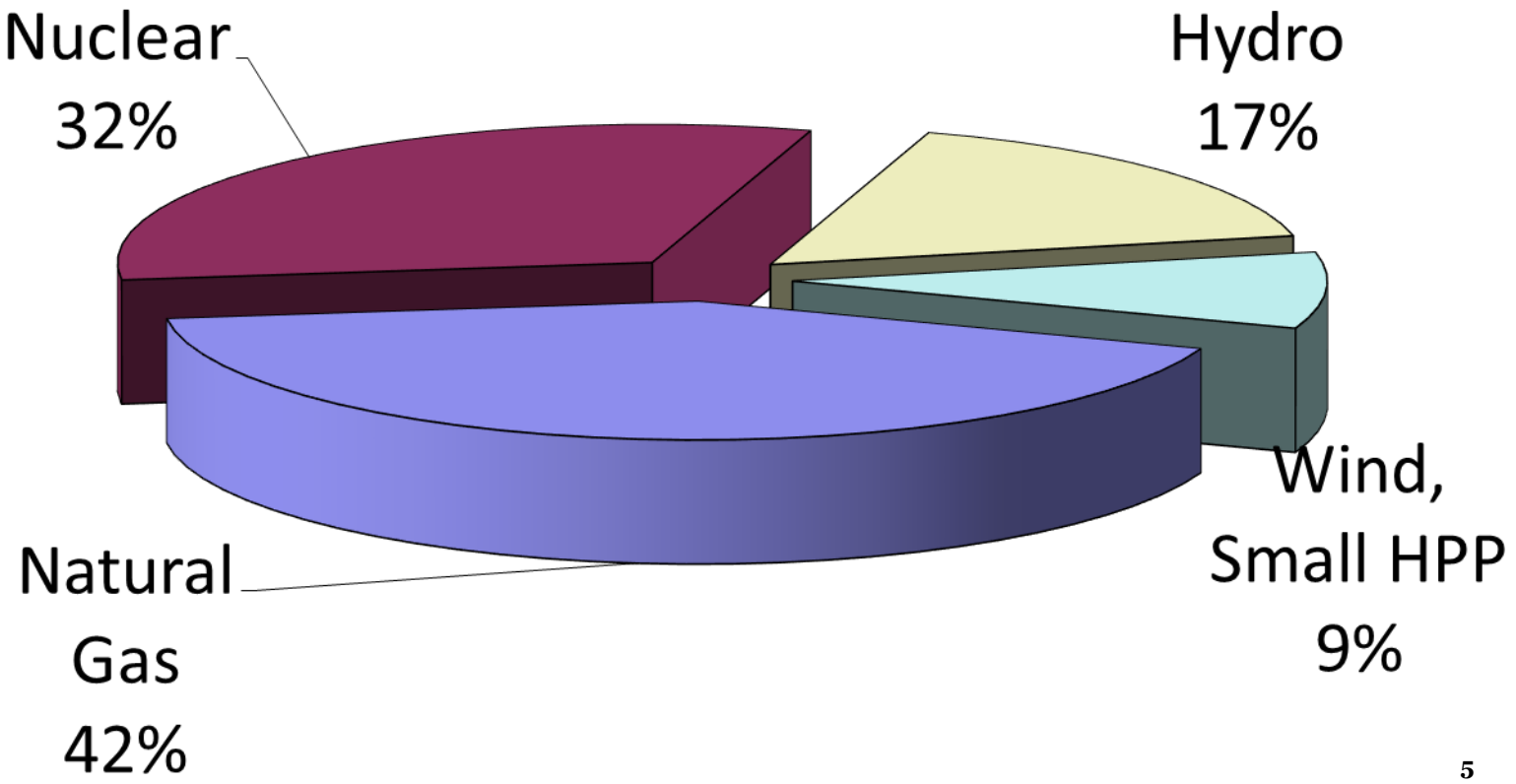
Armenian Power System: Main Indicators (as of 31.12.2014)

Installed capacities (MW)

Armenian NPP (VVER-440)	440
Hrazdan TPP	810
Hrazdan unit 5	440
Yerevan CCPP	242
Sevan-Hrazdan Cascade of HPPs	561
Vorotan cascade of HPPs	404
Small HPPs (<30 MW)	220
Wind Farm	2.6

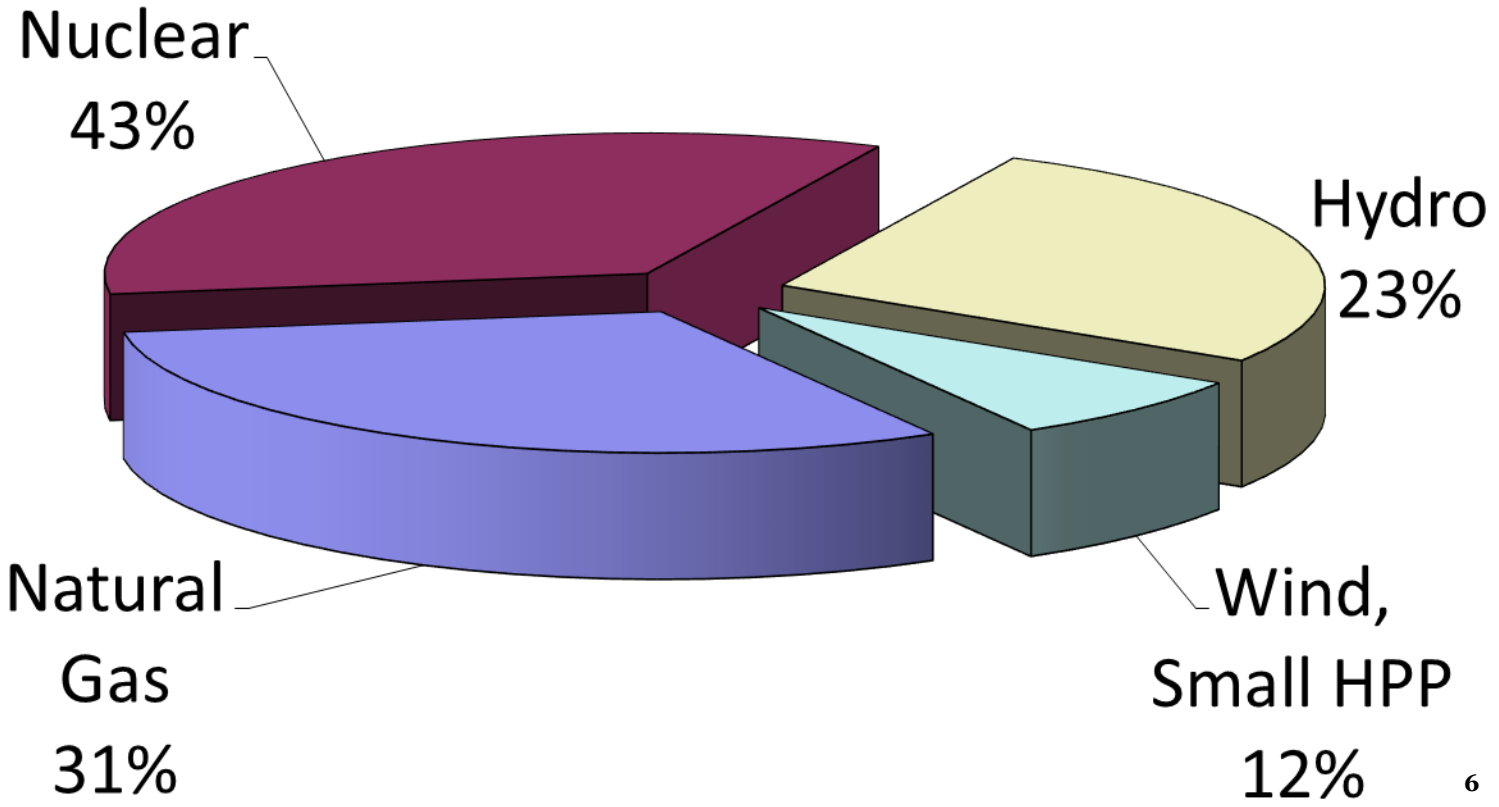
Armenian Power System: Main Indicators (as of 31.12.2014)

Shares of electricity production (total)

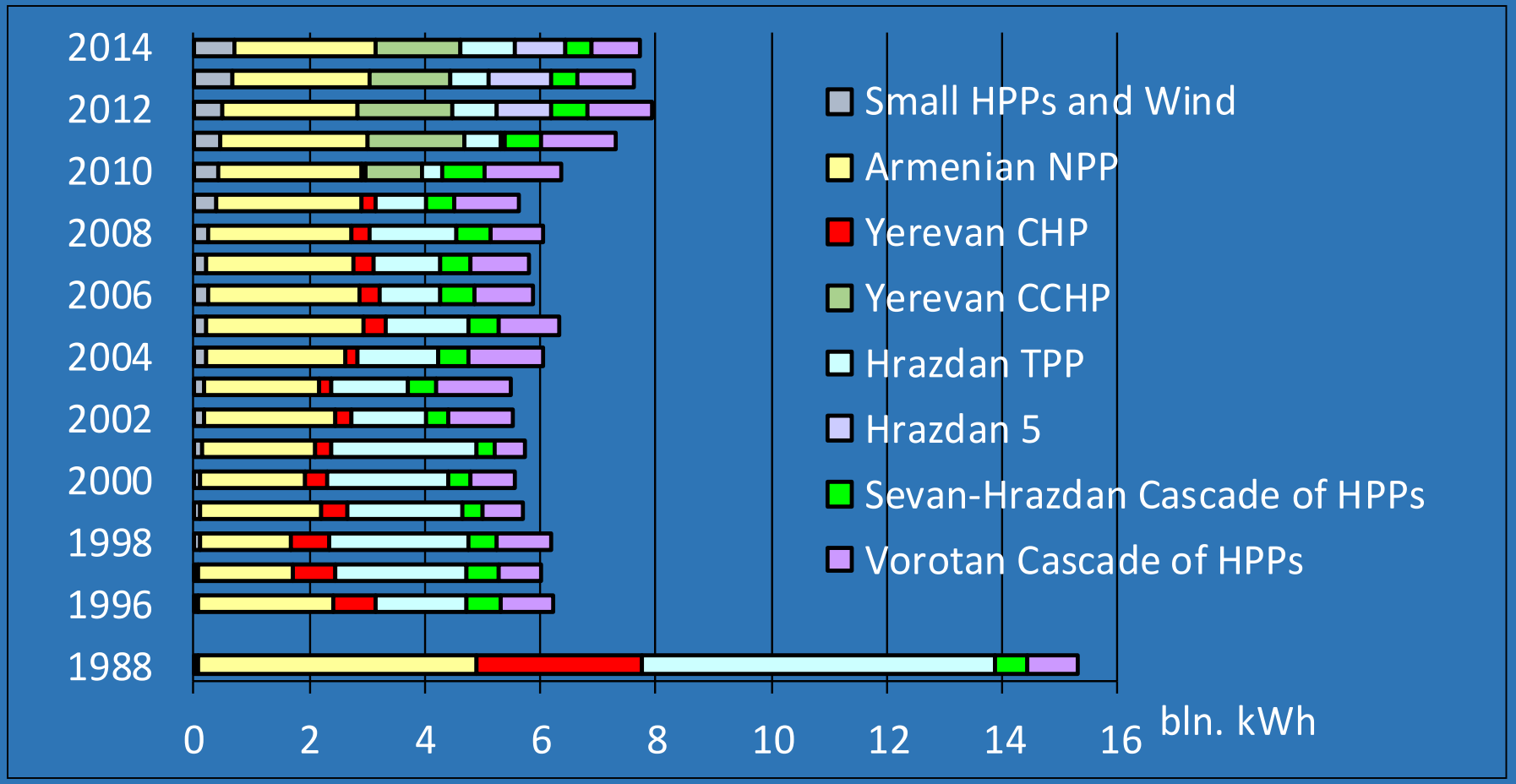


Armenian Power System: Main Indicators (as of 31.12.2014)

Shares of electricity production (domestic)



Armenian Power System: Main Indicators (as of 31.12.2014)



Customers Electricity Tariffs:
(effective from 17th of June, 2015)

1 $ = 478 AMD
(average for 2015)

Connection Voltage/Sector	***Tariff, AMD (USc)/kWh***	
	Night-time	*Daytime*
110 kV and above	33.28 (6.96)	37.28 (7.80)
35 kV	35.78 (7.49)	39.78 (8.32)
6(10) kV	35.78 (7.49)	45.78 (9.58)
0.38 kV	38.78 (8.11)	48.78 (10.21)
Residential	38.78 (8.11)	48.78 (10.21)

Electricity Generation Tariffs: Main Power Plants

(without VAT – 20%, effective from 17th of June, 2015)

1 $ = 478 (average for 2015 AMD

Power Plant	Unit	Tariff
Armenian NPP:		
Capacity Tariff	AMD(US$)/kW/month	3608.78 (7.55)
Electricity Tariff	AMD(USc)/kWh	4.597 (0.96)
Hrazdan TPP:		
Capacity Tariff	AMD(US$)/kW/month	957.7 (2.00)
Electricity Tariff	AMD(USc)/kWh	35.775 (7.48)
Hrazdan unit 5:		
Electricity Tariff	AMD(USc)/kWh	35 (7.32)
Yerevan CCPP:		
Capacity Tariff	AMD(US$)/kW/month	3564.11 (7.46)
Electricity Tariff	AMD(USc)/kWh	18.5 (3.87)

Electricity Generation Tariffs: Main Power Plants (without VAT – 20%, effective from 17th of June, 2015)

1 $ = 478
(average for 2015 AMD

Power Plant	***Unit***	***Tariff***
Sevan-Hrazdan HPP Cascade:		
Capacity Tariff	AMD(US$)/kW/month	629.85 (1.32)
Electricity Tariff	AMD(USc)/kWh	4.135 (0.87)
Vorotan HPP Cascade:		
Capacity Tariff	AMD(US$)/kW/month	1184.72 (2.48)
Electricity Tariff	AMD(USc)/kWh	4.562 (0.95)

Electricity Generation Tariffs: Renewables (without VAT – 20%, effective from 1st of January, 2015)

1 $ = 478
(average for 2015 AMD

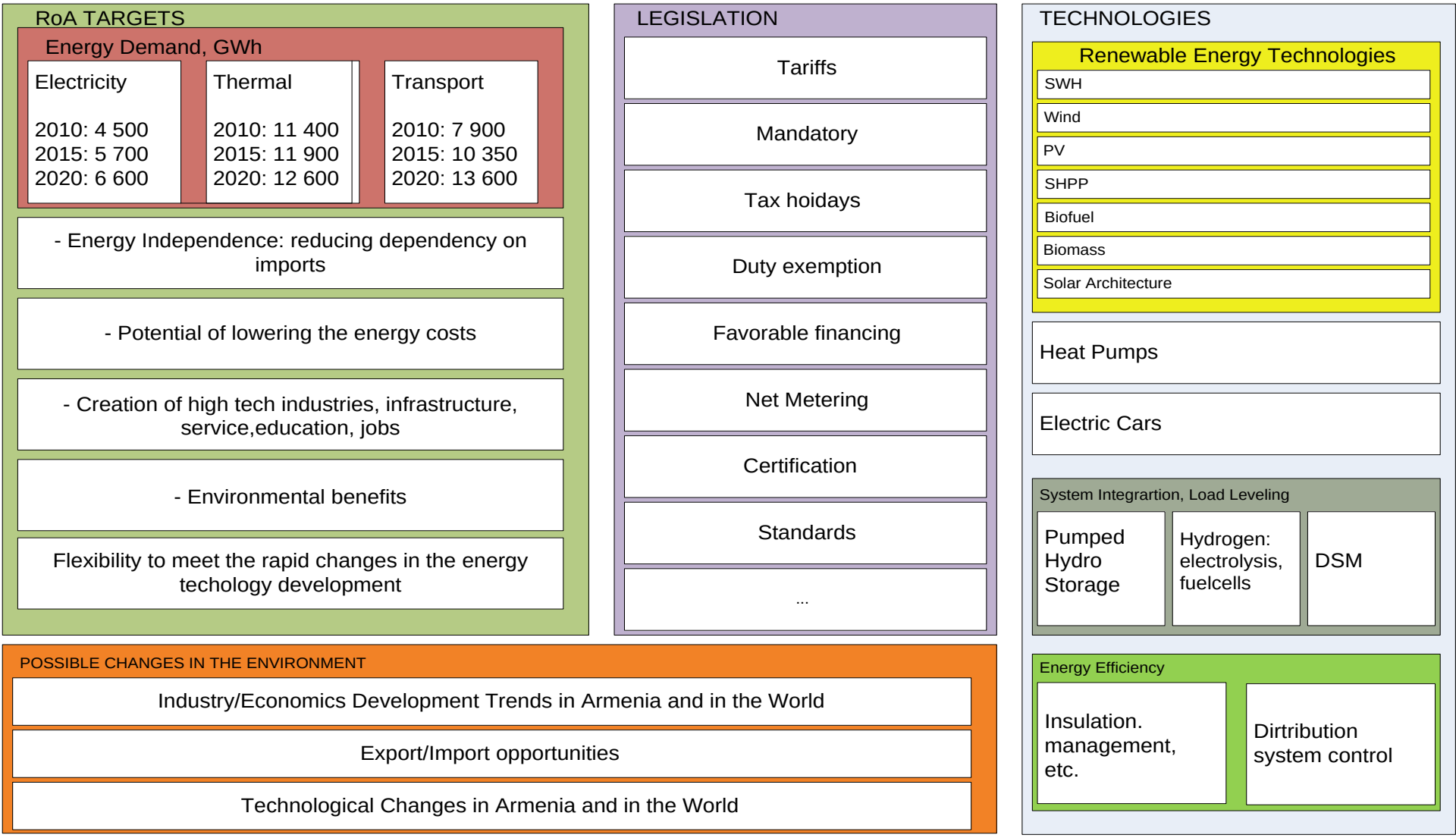
Power Plant	***Tariff,*** AMD(USc)/kWh
Small HPPs:	
Build on drinking water pipeline	9.408 (1.97)
Build on irrigation system	14.110 (2.95)
Build on natural water flow	**21.168 (4.43)**
Wind Power Plant	38.005 (7.95)
Power Generated from Biomass	40.542 (8.48)

RoA Goals

- The *RoA Roadmap targets* set the priorities in the development of the RE and the energy system such as:

1. Energy independence
2. Potential of lowering the energy costs
3. Creation of high tech industries
4. Environmental benefits
5. Responsiveness to the technological and business changes in the world

Vision. Variables/factors: RoA Goals, Technologies, Flexibility, Legislation

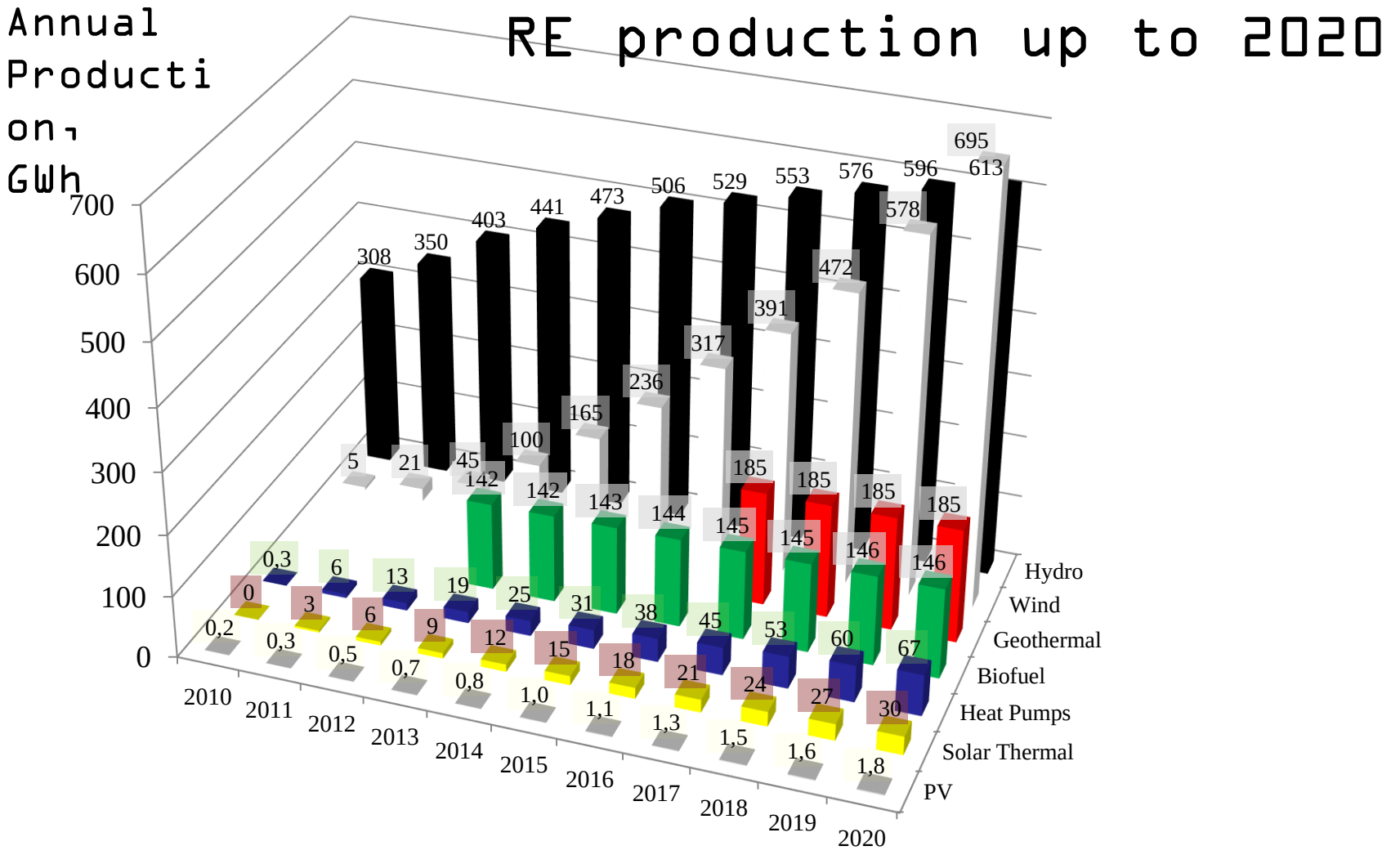


Preparation of the Renewable Energy Development Roadmap of Armenia (REDRA)

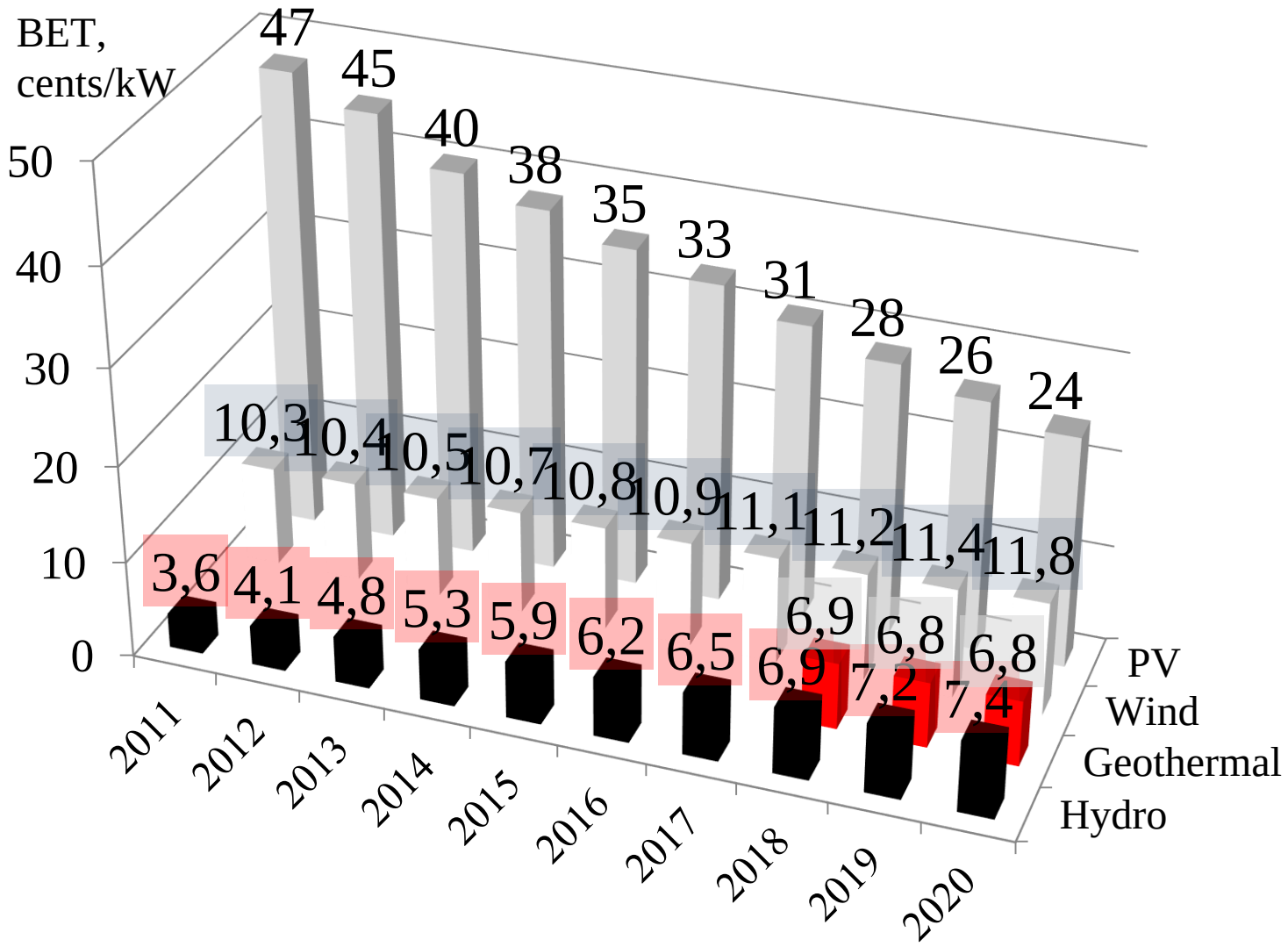
2011

Danish Energy Management
A part of Danish Management Group

Base Case RE Output



Comparison of BET Trends for Selected RETs



Fleet of Electric Vehicles in the light of the new NPP?

- The 100% dependency of the republic on the imported fuel would be eliminated.
- Load levelling: charging at night is serving as a natural means of load levelling.
- Not releasing of an equivalent of million tons of CO_2 every year.
- The air quality in the major cities.

The success story – Small Hydropower

- Tariff start to set almost 10 years ago by the Public Services Regulatory Committee (PSRC) and revisited every year.
- Current tariff ~ **21AMD = $0.044**
- **> 2/3 Bln kWh** production annually.
- **> 12%** of total domestic electric energy produced.

Small Hydropower - Problems

¢

- Potential almost exhausted
- Most easily accessible sites already gone
- Environmental concerns

What's next - PV

- The roadmap scenarios
- The SREP project
- Currently the Net metering law developed:
- If **< 150 kW** PV stations do not need any licensing, including the grid connection.
- Annually balance is calculated, extra generation is paid per 50% of the power tariff.
- If **> 150 kW** stations a special tariff should be set on competitive basis.
- Rumors for tariff is around **60 AMD = $0.125** per kWh

SREP – Solar Armenia Project

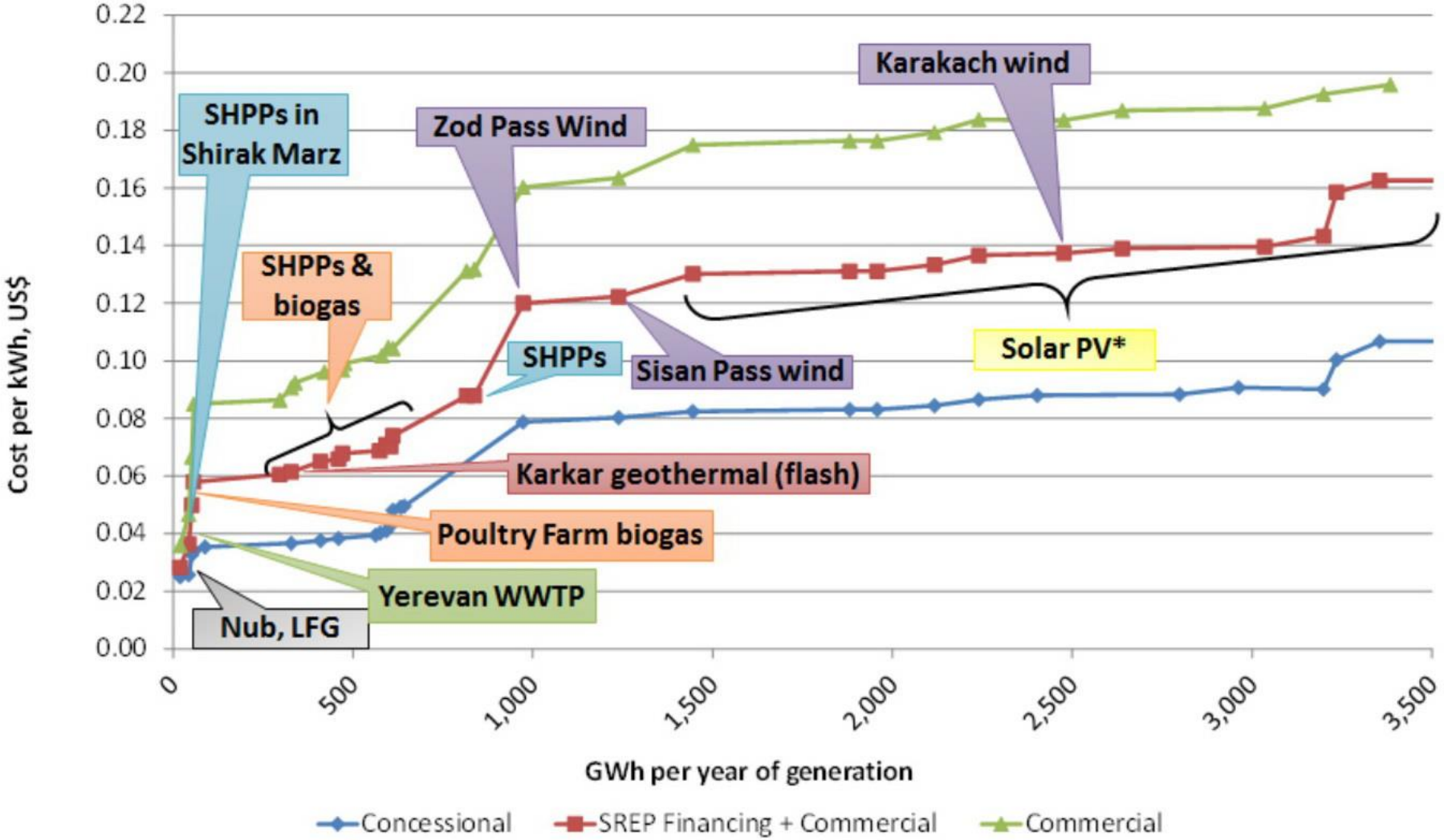
- Scaling up Renewable Energy Program (SREP) - Armenia
- World Bank helping to finance the country's first 40-50 MW of utility-scale solar PV
- Total Fuds available up to $300M
- Two resource assessment and site decision pre-projects already short listed.

WORLD BANK GROUP

R2E2

Investment Plan for Armenia

Figure 1.1: Renewable Energy Resources Supply Curve for Armenia, Commercial, Mixed Commercial/SREP and Concessional Financing



An important REDRA outcome

- The transition to increased use of RE while providing energy security and flexibility to a country **should be empowered** by a sufficiently strong technological, scientific and educational basis as well as an infrastructure, which is well integrated to the world RET community.

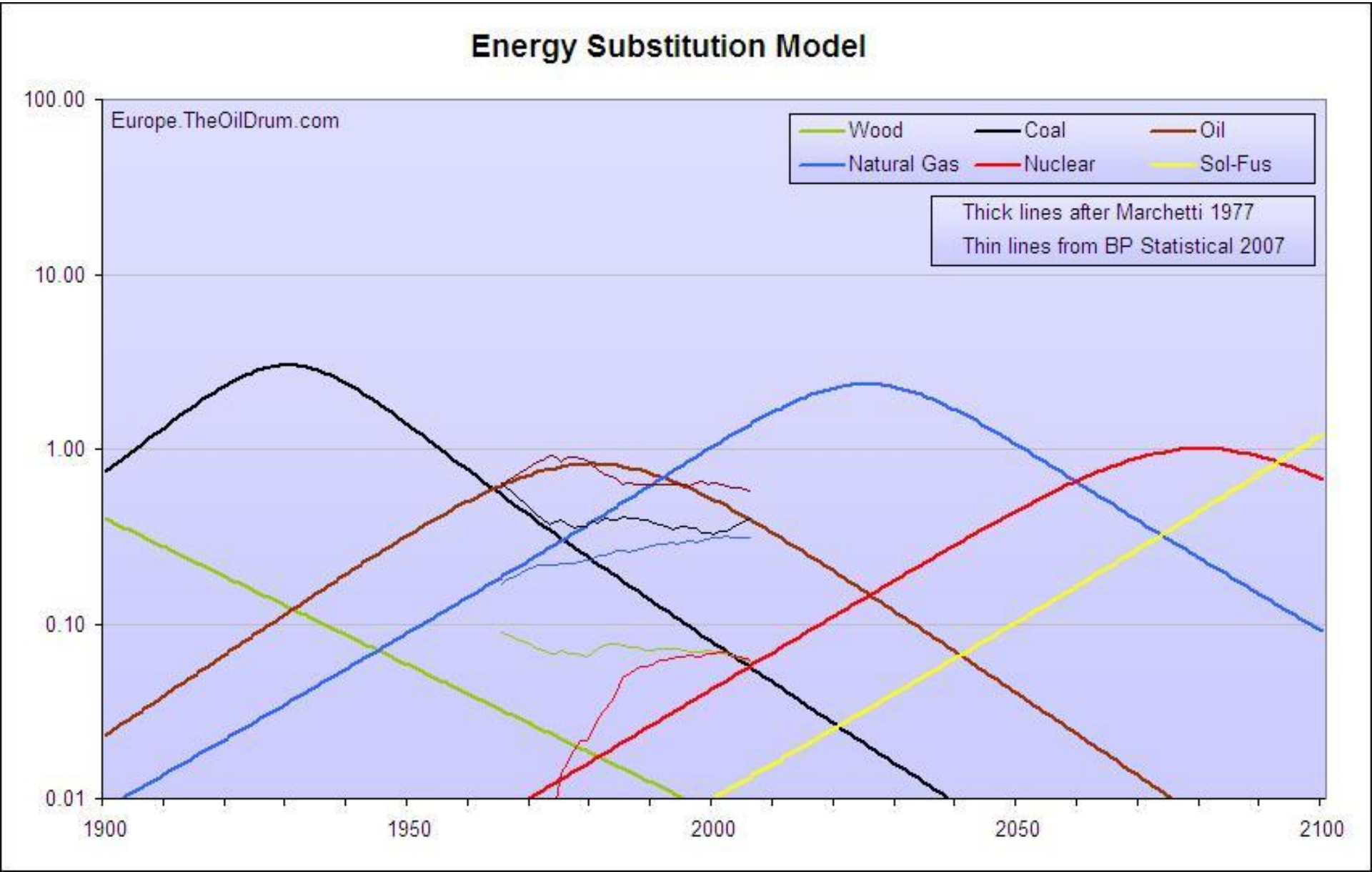
An important REDRA outcome

- Investment in the RE infrastructure, and importantly to its scientific and educational components could be much more effective compared to any other area, taking into consideration that the RETs in the whole world have 1000-fold growth potential.

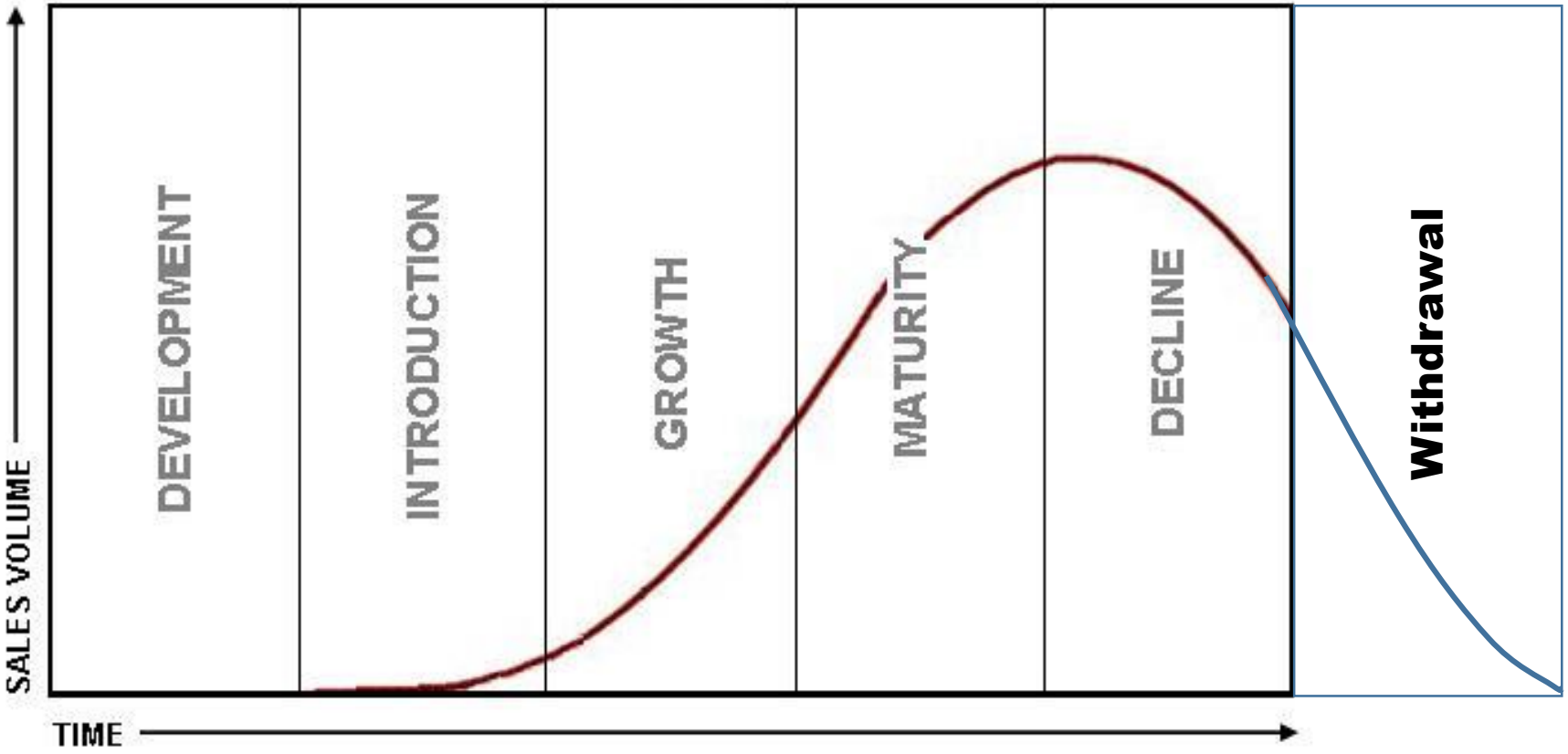
Armenian Economy

1. What value does it currently create?
2. Which direction we shall move?

Similarity to energy technology peaking



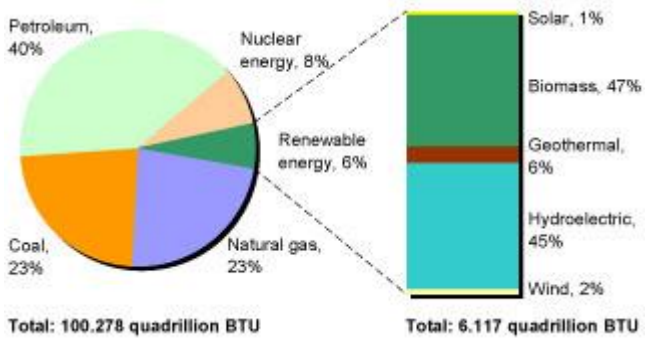
Product lifecycle

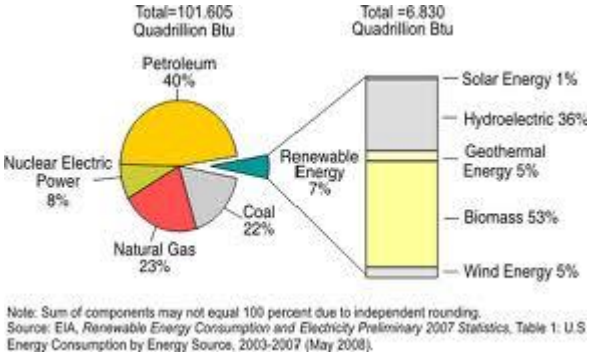


RET potential

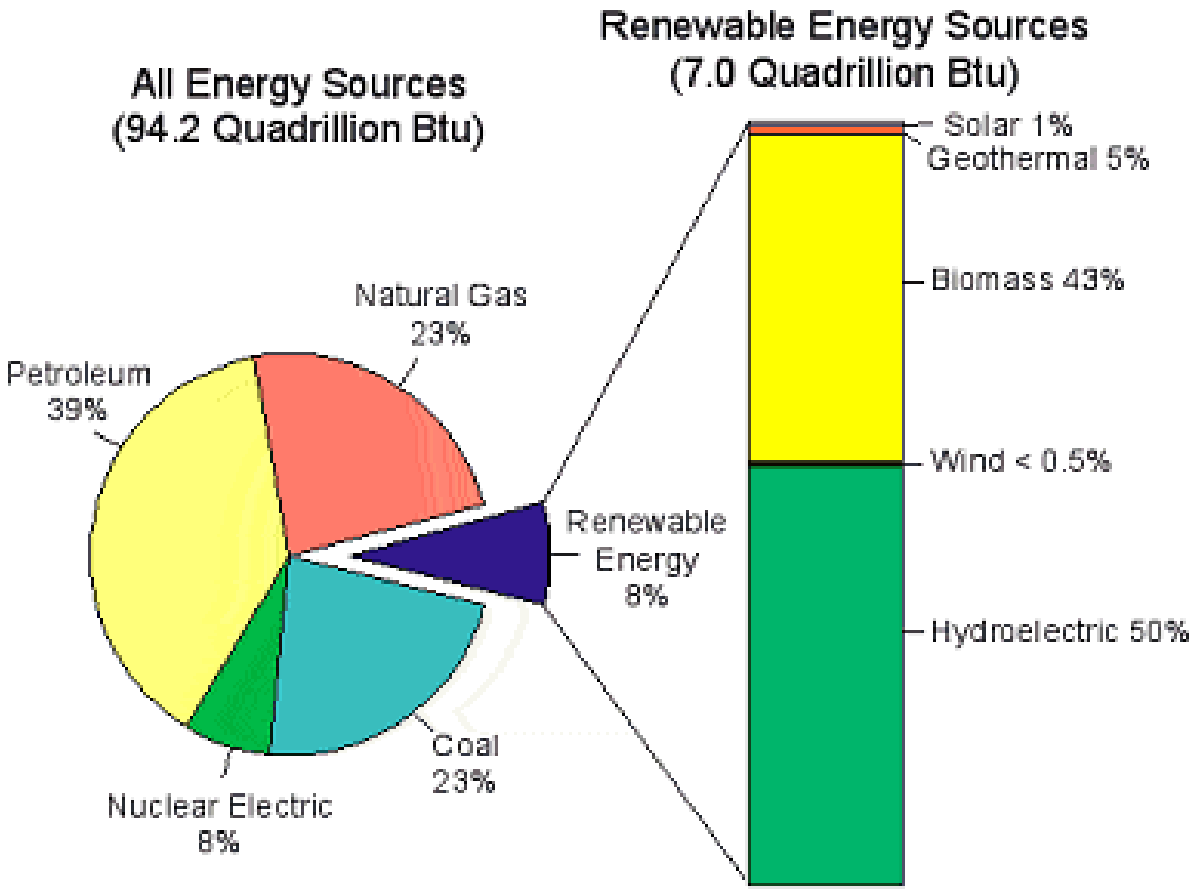
- Renewable Energy development potential is:

> 1000 x !





Note: Sum of components may not equal 100 percent due to independent rounding.
Source: EIA, *Renewable Energy Consumption and Electricity Preliminary 2007 Statistics*, Table 1: U.S Energy Consumption by Energy Source, 2003-2007 (May 2008).



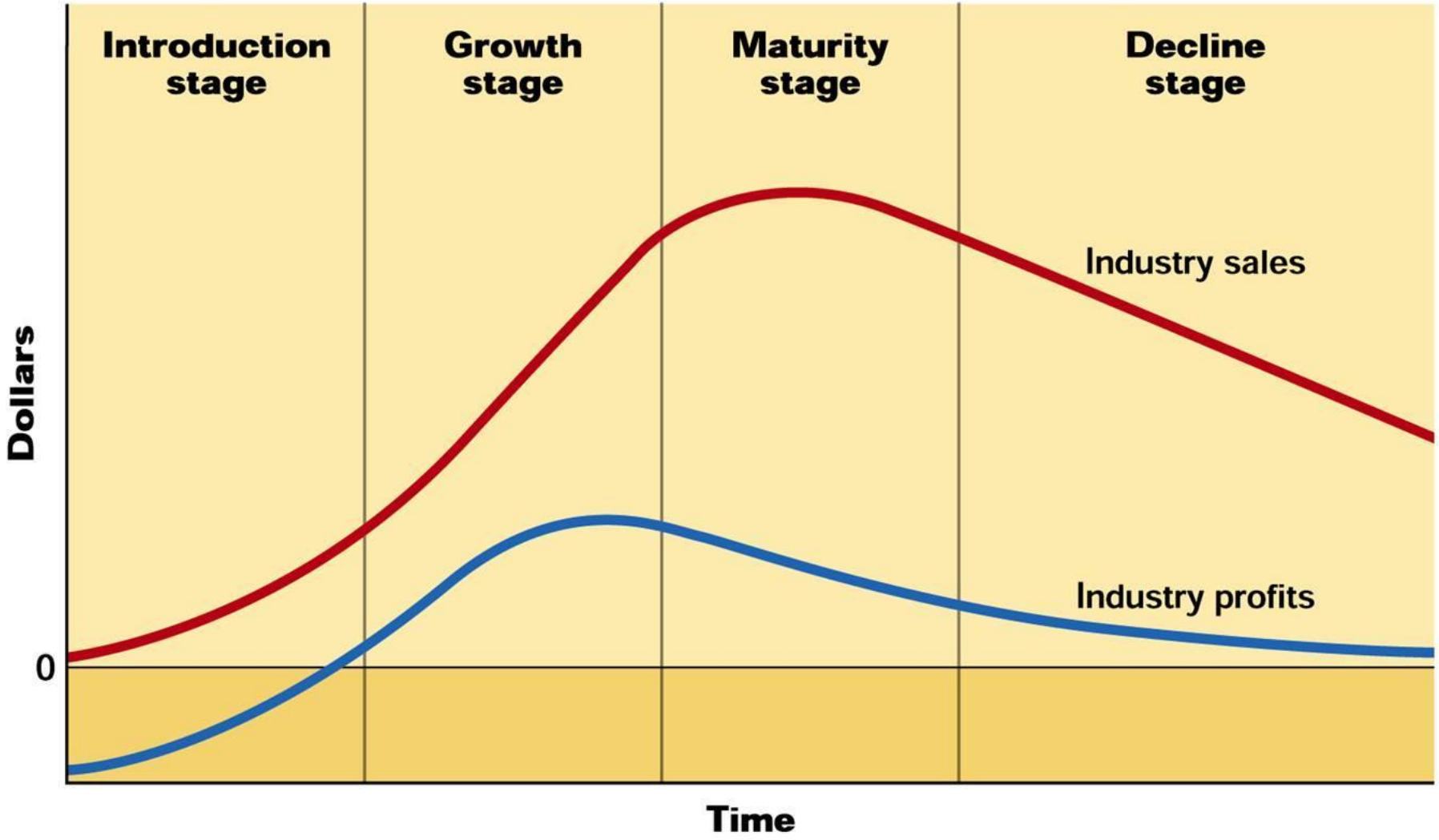
Main two paths for a country

- China's path – take outsourcing from other countries from the **maturity** stage.
- **Product development and Introduction** stage – start your own research for product development.

take outsourcing from the **maturity** stage

- It allows to obtain track of record in Industry
- Allows to start building infrastructure:
  - properly tailored educational system
  - multitude of businesses that service this industry by components, design and engineering, procurement paths
- Most importantly cadre that is experienced in the industry that operates in the world market.

Mature production terms may allow long periods for industry creation



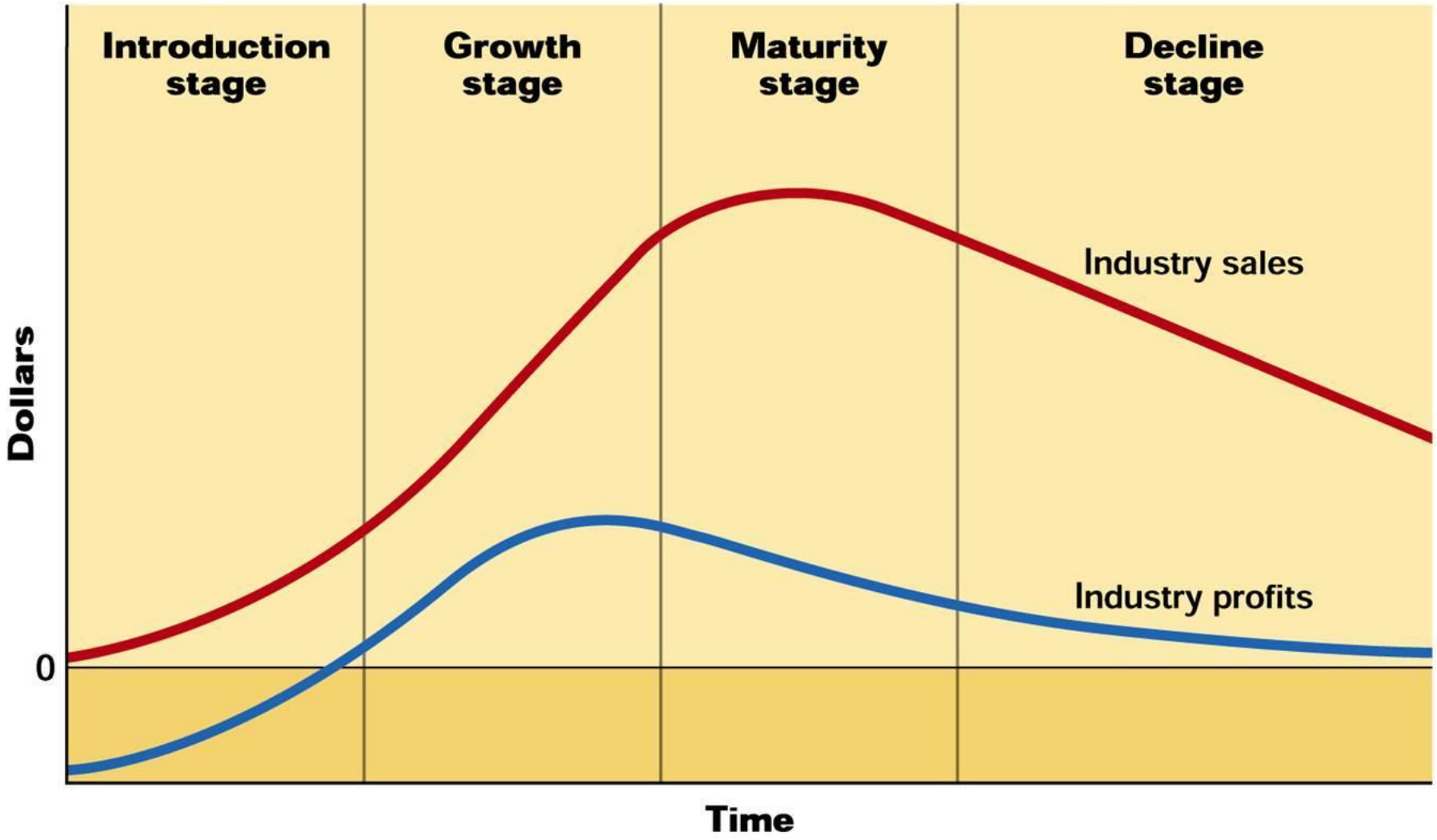
China's path in PV

- What has been the magic of the price drop in 2011-12?
- Mostly no dumping!
- China still works via Pyatiletka-s, the 5-year plans!
- But the economic "muscles" are capitalistic…

China’s path in PV

- In a few 5-year plans China managed to organize the production of ***the means*** of the production!
- Became virtually independent from other countries.
- Leverage on Chinas infrastructure, inexpensive labor force, and excellent, sinergestic organization.

Let's focus on innovation!



RET-s provide

- Huge multitude of various aspects of science, research and development
- A few issues are conceptual and are yet far to be solved, e.g. the storage area.

Our advantages

- We have always been proud by intellectual abilities.
- We have diaspora – in the case of proper synergy this is much, much more than Azeri oil!
- Look at Israel example.

AREC - Armenian Renewable Energy Center

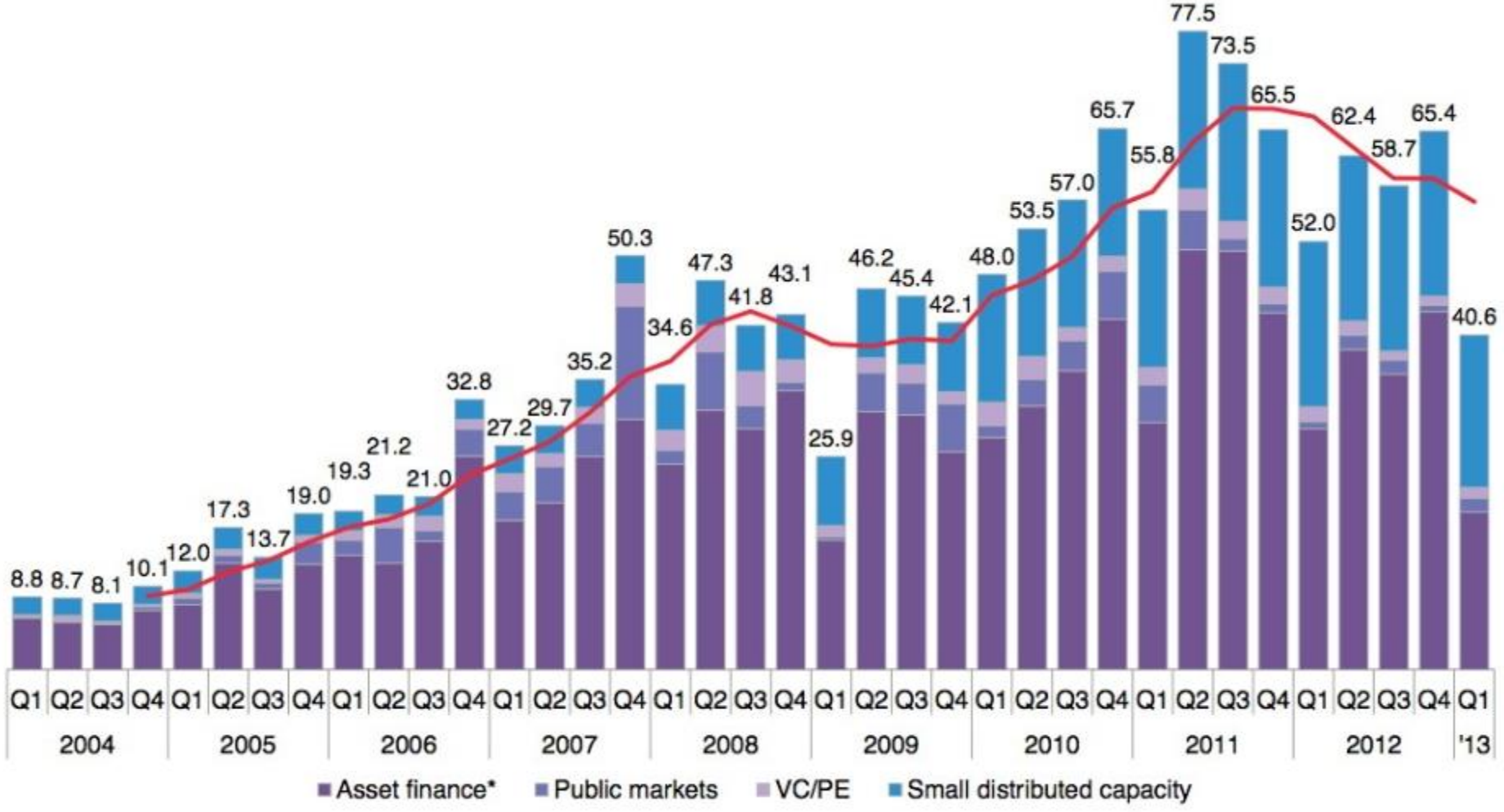
- The mission of the Center is to create a strong renewable energy research and innovation infrastructure in Armenia.
- The Center will benefit from the large global potential that renewable energy provides by initiating, consolidating and substantially strengthening the scientific, engineering and industrial potential of Armenia in RE and thus join the global process of transition from fossil fuels to green technologies.

AREC Functions

1. **Research.** Host and support research in various areas of Renewable Energy Innovation/Incubation.
2. **Innovation/Incubation:** provide facilities and services to RE startups for innovation and private sector development.
3. **Reference Center and resource monitoring.** Serve as reference/certification center for a number of RE measurements.
4. **Policy, Economics, Legislation, monitoring of the Energy Landscape in the World and Armenia.** RE policy development and consulting services.
5. **Exhibit, Visitor Center, RE Shop and proliferation (PR).**

AREC Functions	Possible funding source	
	Start	Eventually
1. Research	**Grants**	**Grants, Industry**
2. Innovation/Incubation	**Grants**	**Grants, Venture Capital**
3. Reference Center and resource monitoring	**Grants**	**Industry, Grants**
4. Policy, Economics, Legislation, and Monitoring	**Grants**	**Industry, Grants**
5. Exhibit, Visitor Center, RE Shop and proliferation (PR).	**Grants**	**Industry, Grants**

VC funding in renewables, USA



Note: Total values include estimates for undisclosed deals. Excludes corporate and government R&D.
Includes small distributed capacity & adjustment for re-invested equity.

Source: Bloomberg New Energy Finance

AREC

- Connections with EU and other countries
- Domestic research
- Clear targets for development, both:
  - satisfying energy demand
  - economic development avenue
- …

AUA - GREEN BUILDING/TECHNOLOGY LAB

- Energy efficiency
- Renewable energy
- Water efficiency and sustainable use
- Solid waste management and recycling

Additional slides

1. **Research.** Host and support research in various areas of Renewable Energy that are of vital interest in Armenia (*prioritization requires additional effort*). Renewable energy can be categorized in the following main directions:
   - Electric power generation
   - Heating, cooling and energy efficiency
   - Transportation

   In each of these areas there are many sub-disciplines where research and development is being conducted worldwide. More specifically, Renewable Energy areas include (but are not limited to):

   1.1 Energy efficiency
   1.2 Solar Architecture: passive structures
   1.3 Solar thermal: water heating (SWH); solar heat processing; etc.
   1.4 Solar Lighting
   1.5 Smart windows
   1.6 Heat pumps
   1.7 Solar thermal electricity
   1.8 Photovoltaic (PV)
   1.9 Wind power
   1.10 Small hydro
   1.11 Hybrid systems
   1.12 Energy from waste
   1.13 Energy Storage: thermal
   1.14 Energy Storage: electricity – batteries, fuel cells.
   1.15 Bio-fuel
   1.16 Electric vehicles
   1.17 Energy modeling – could be coupled with other groups, e.g. monitoring of consumption and energy resources
   1.18 …

Perovskite!

Certainly there is a huge possibility to establish and develop any of the mentioned directions further, e.g. for PV (and any other area) a large number of possible development potentials exist. Importantly, e.g. for overall development of PV in Armenia certain directions may (underlined) or may not play "infrastructural role", each of them being an important research area (as shown in the box below.

Each direction may have a number of research subdirections, as in the case of the Photovoltaics (PV):

- Growing Silicon (E and PV grades)
- Diffusion
- Front contact
- Rear contact
- Surface coating for passivation and optical performance
- Surface characterization (PVSCAN sits here) … etc…
- Thin film (by itself a huge number of directions, many of which could also be infrastructural)
- Organic PV
- Quantum dot cells
- …etc…

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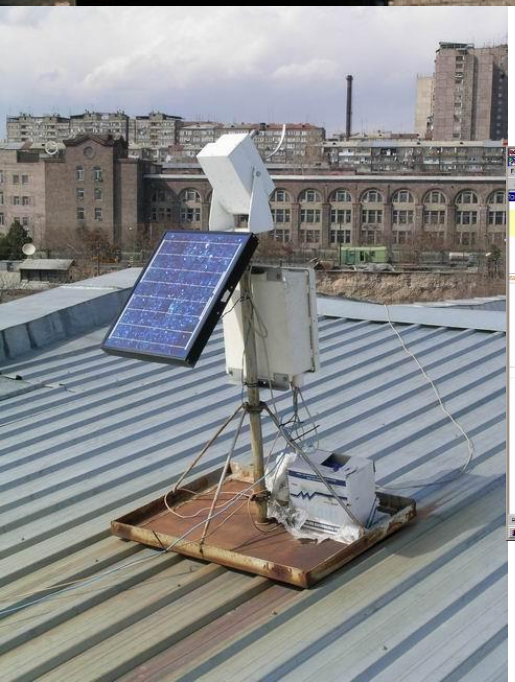
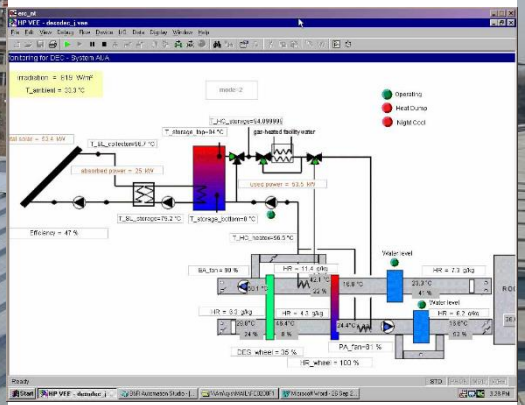
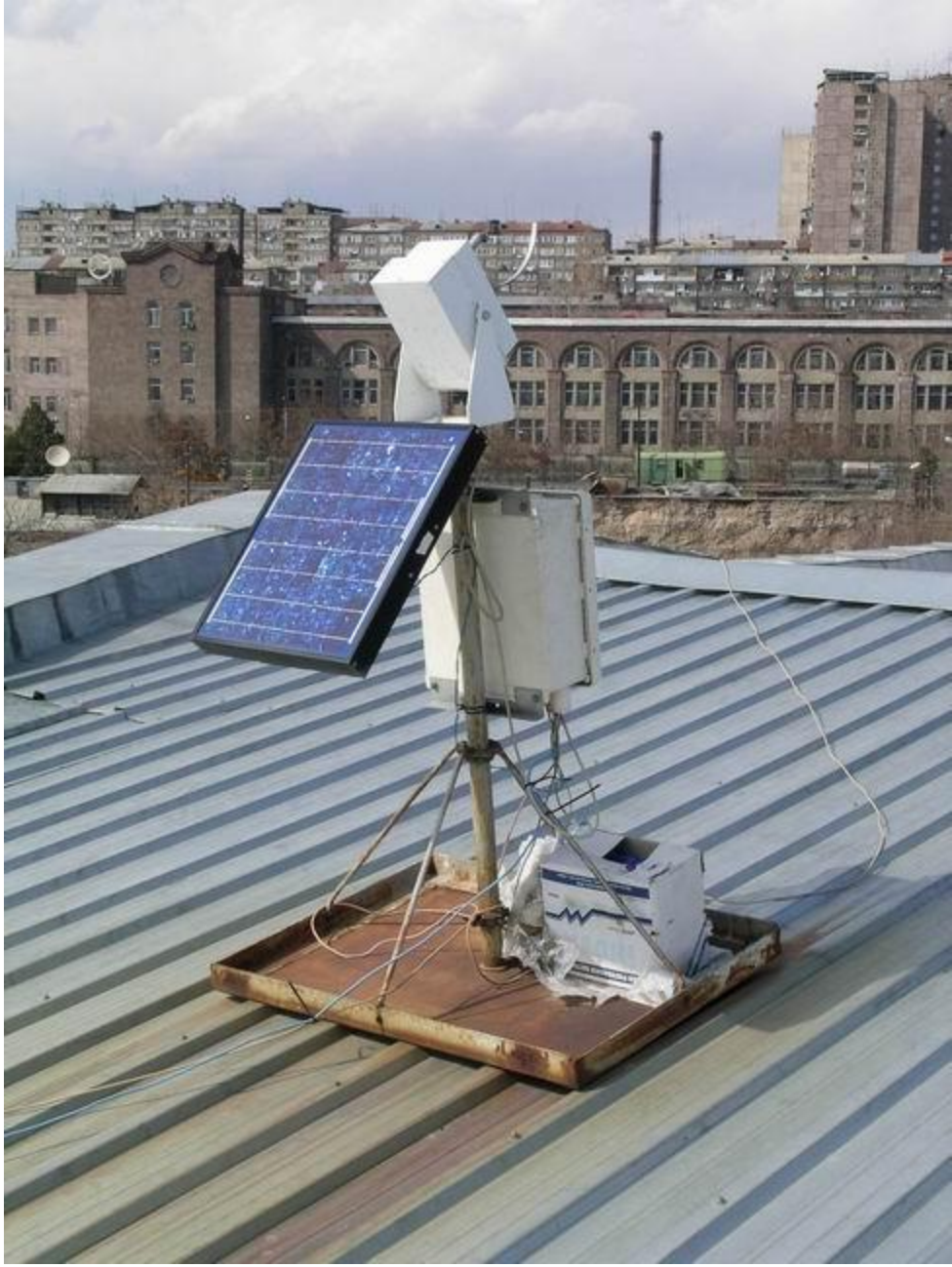




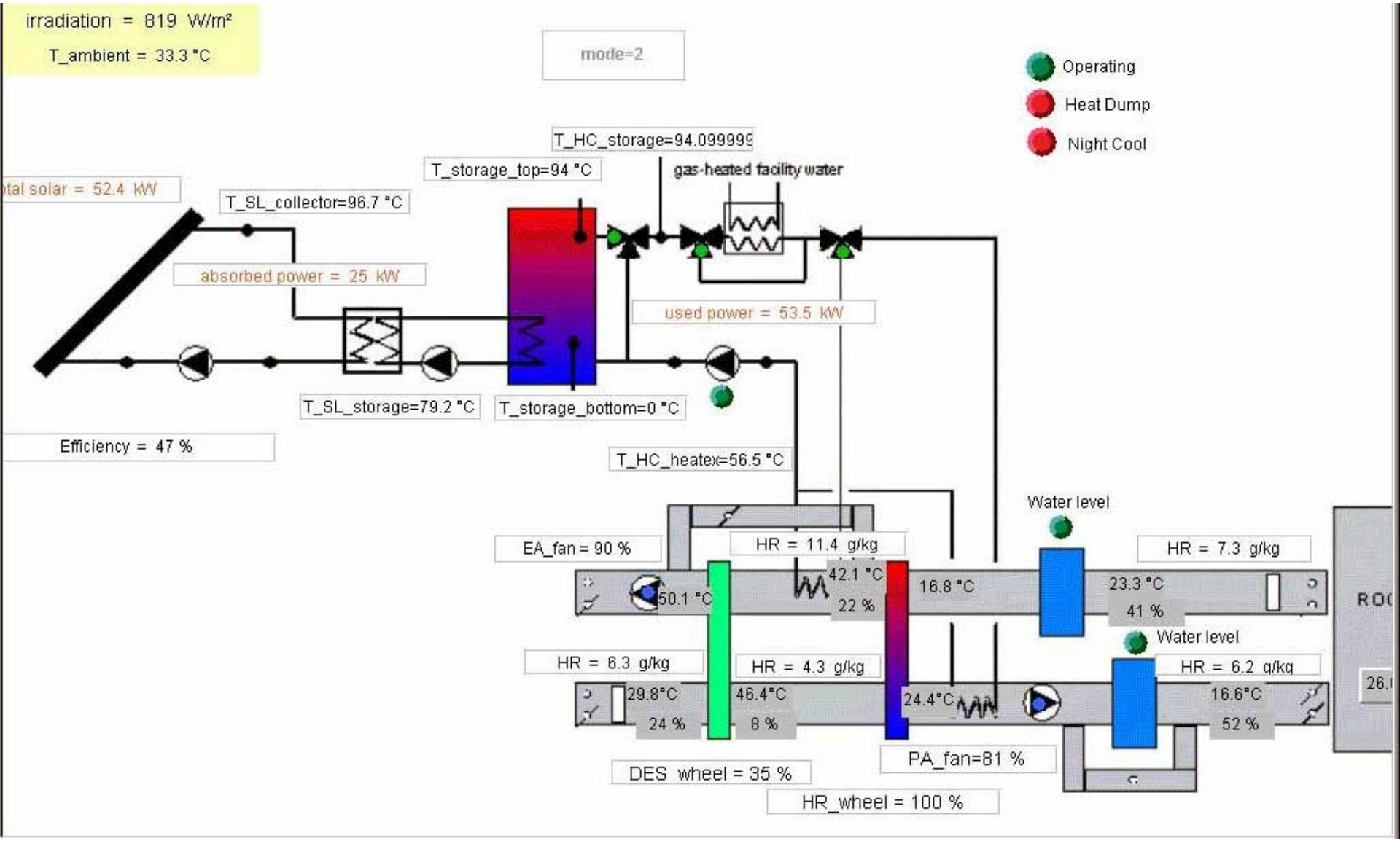
AUA Solar Monitoring Station Collecting data since 1995



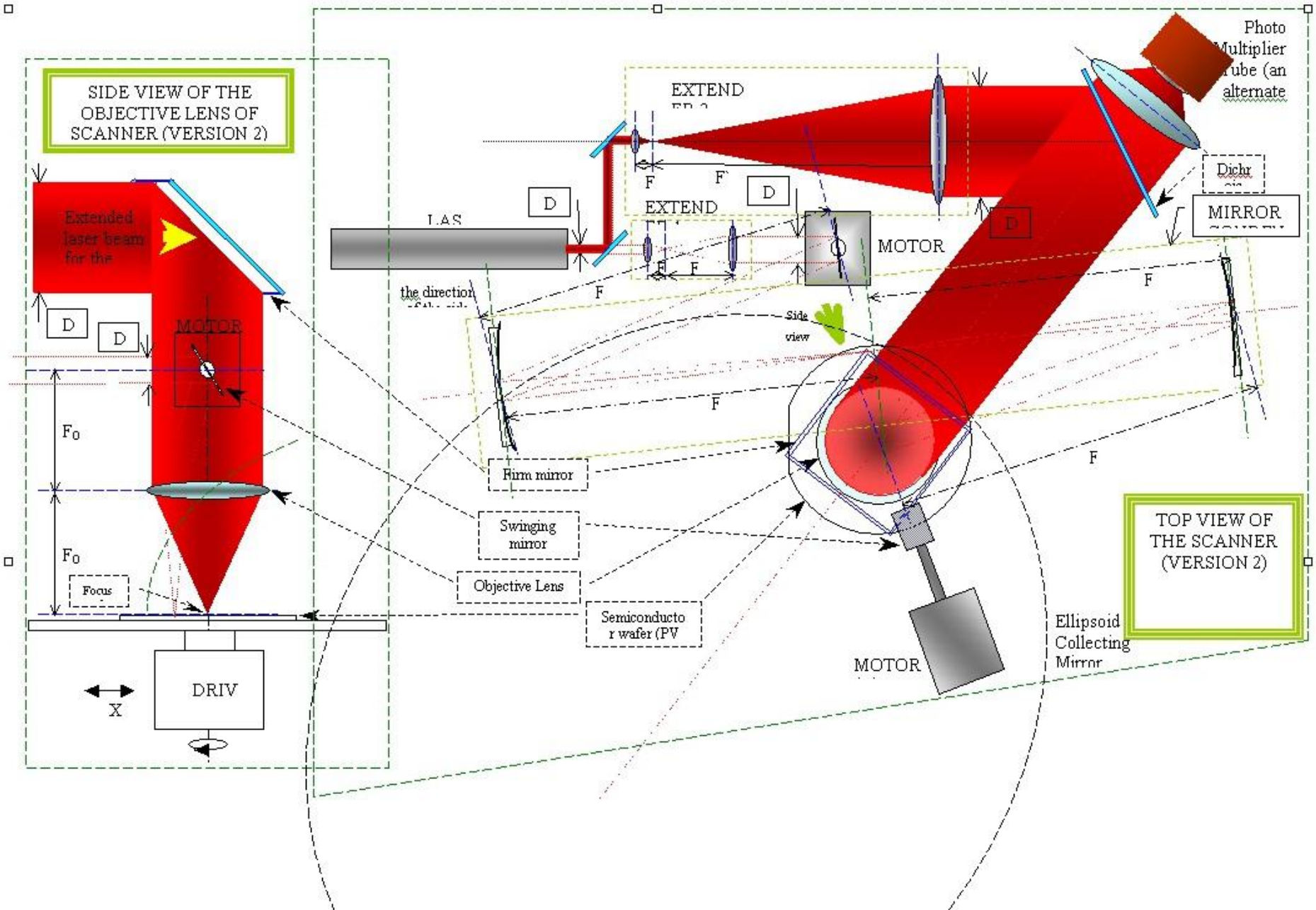
DESODEC: Contact-A; InterSolarCenter; ISE Fraunhofer; DER INETI

AUA Photovoltaic System

Desiccant Cooling

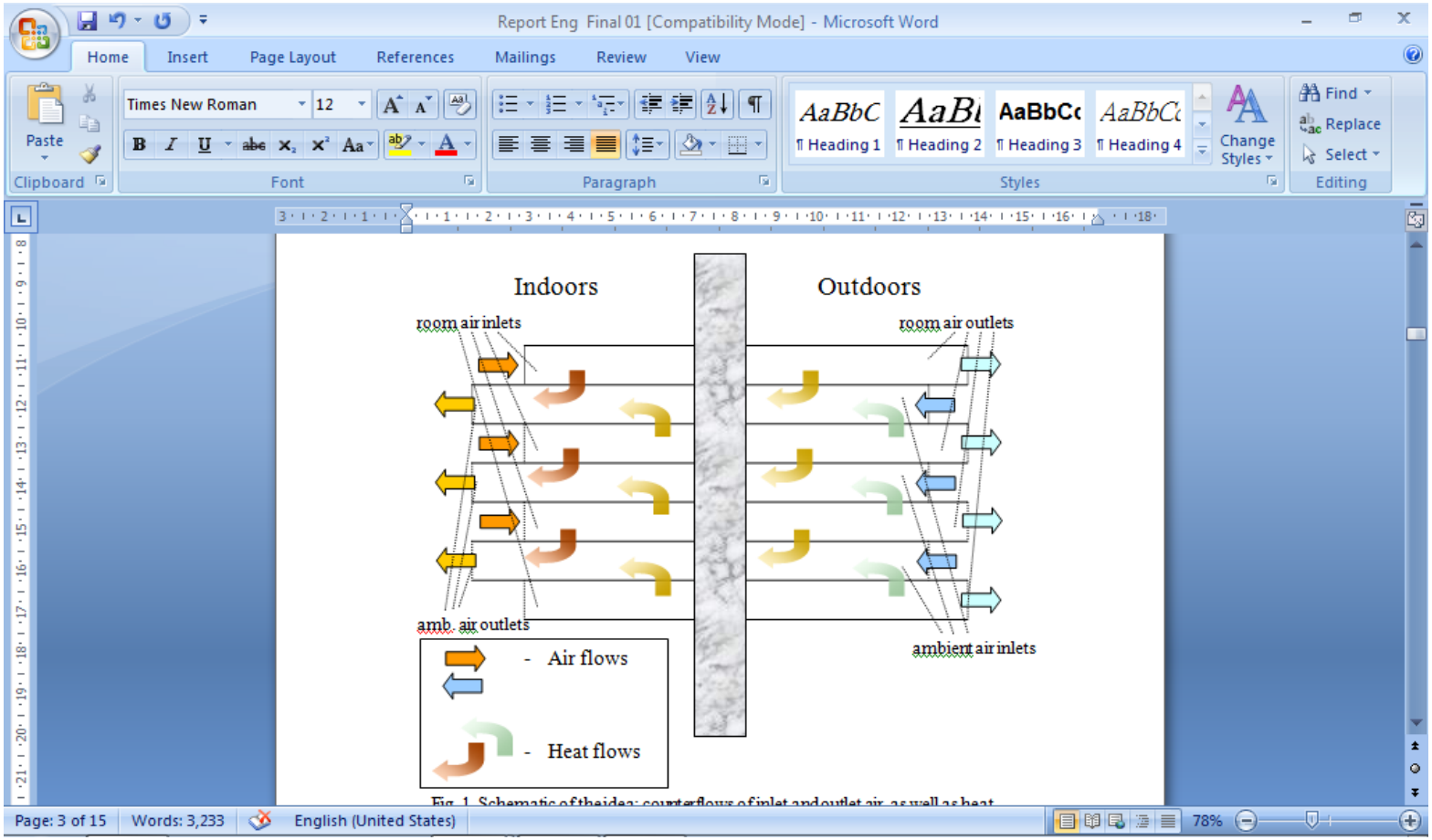


PVSCAN – NREL, USA



Air-to-Air Heat Exchangers

Counter-flows of inlet and outlet air, as well as heat transfer process for winter case is shown

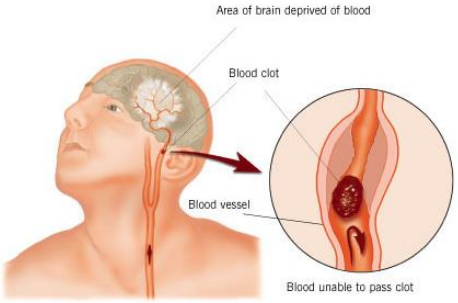


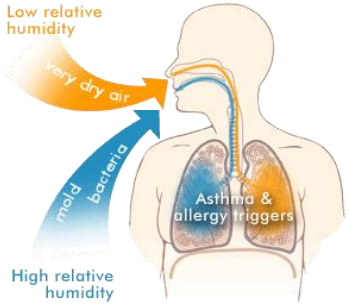
1. The Pain – Lack of Ventilatio

Per standards of 20-40m^3/h per person,

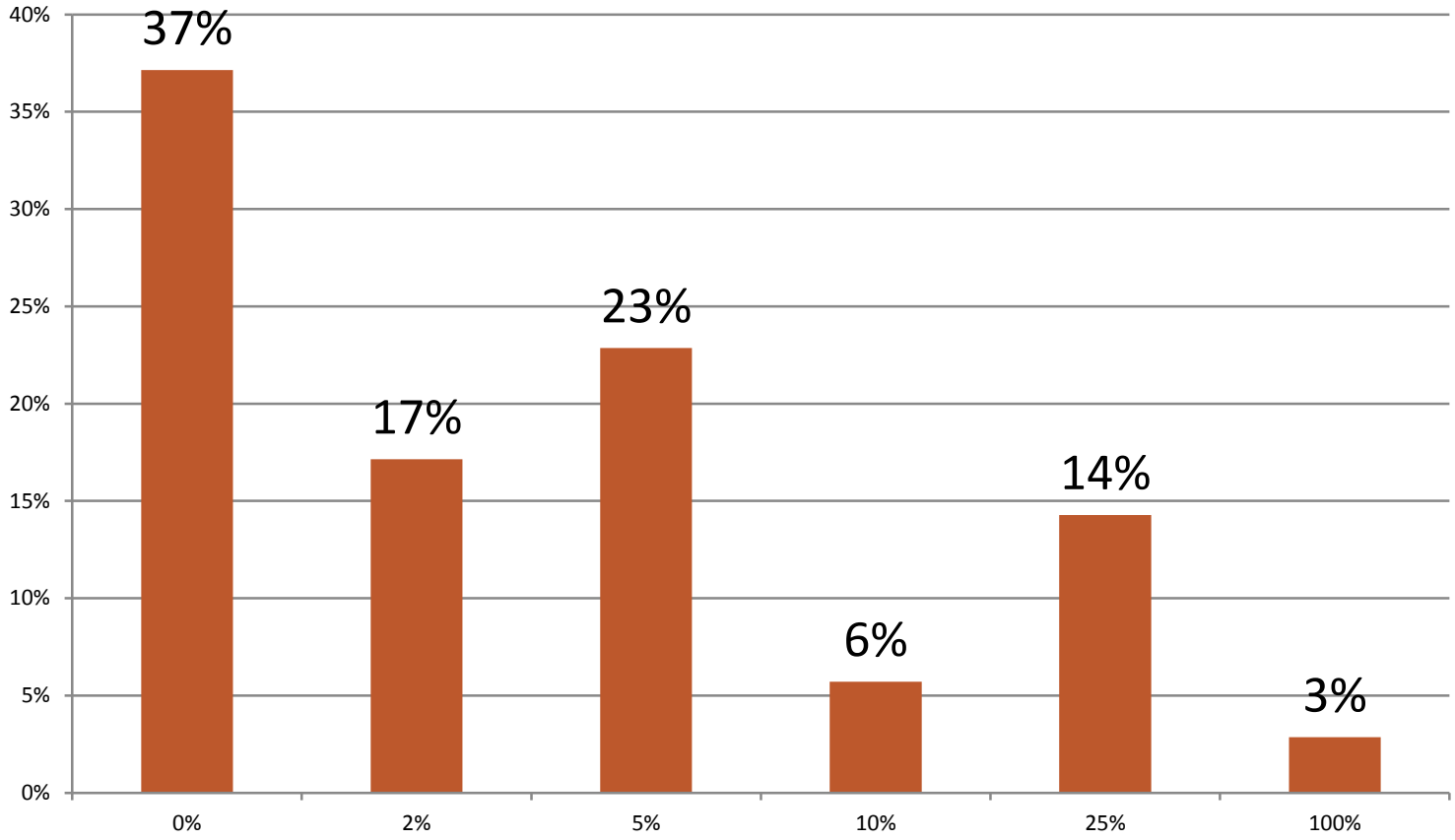
Lack of it causing:

- *Hypoxia*
- *Virus expansion*
- *Stagnation of air*
- *Excess of CO_2*
- *Bad humidity control*





1. The Pain – Result of questionnaire



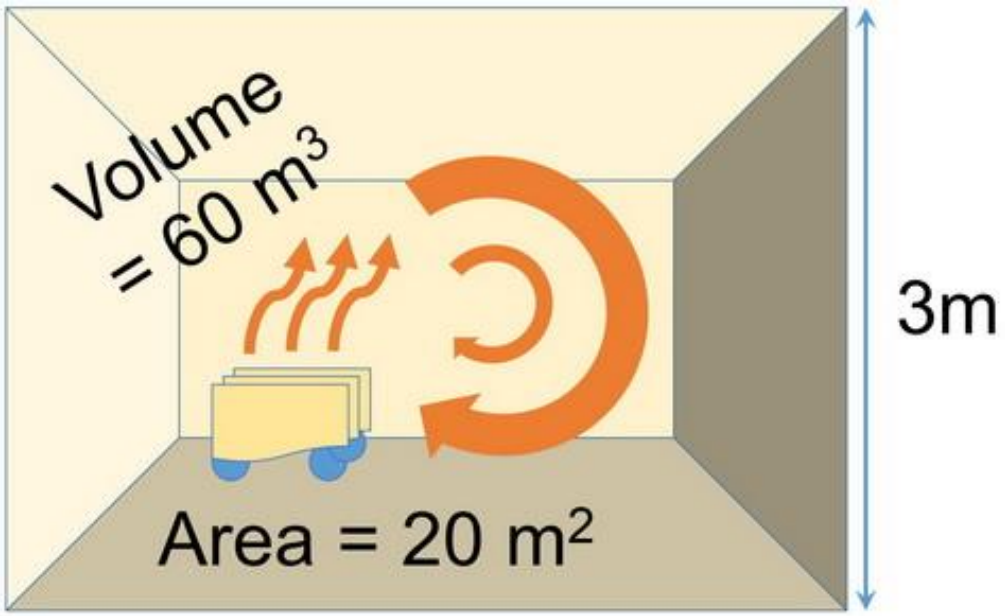
- 83% gets ventilation at the rate of less than 1/10 of what standard requires – 20-40m^3/h per person.

1. The Pain

Current Situation:

•Soviet heritage:

It is assumed that if you have a window then you comply to the standard.



For 2 people the 60m³ of air should be 100% refreshed in 1 hour.

1. The Pain in Construction Industry

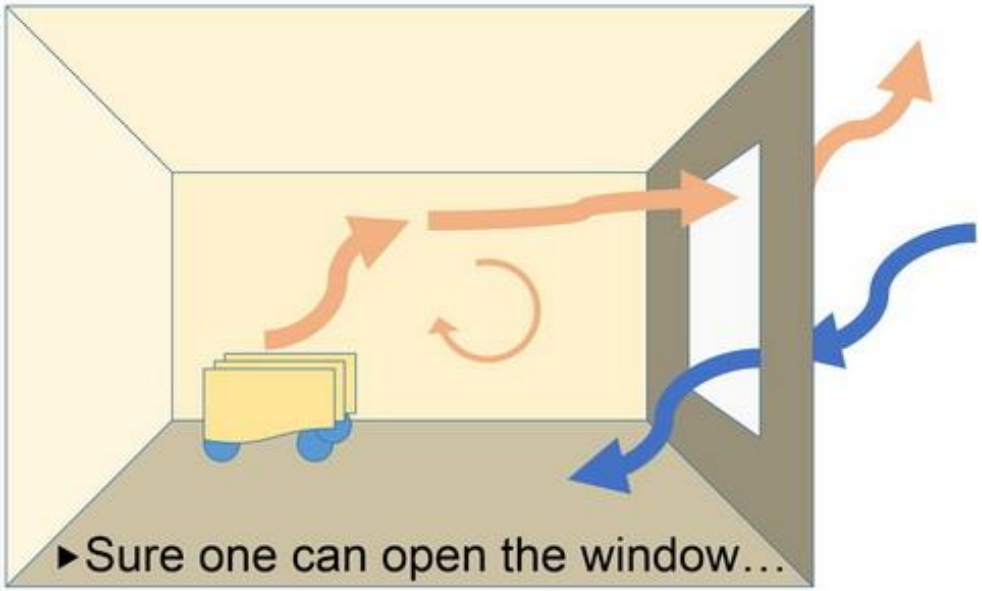
1. You may want to prevent noise getting in

2. You want to filter out the dust

3. You would like to prevent pests, insects and other critters

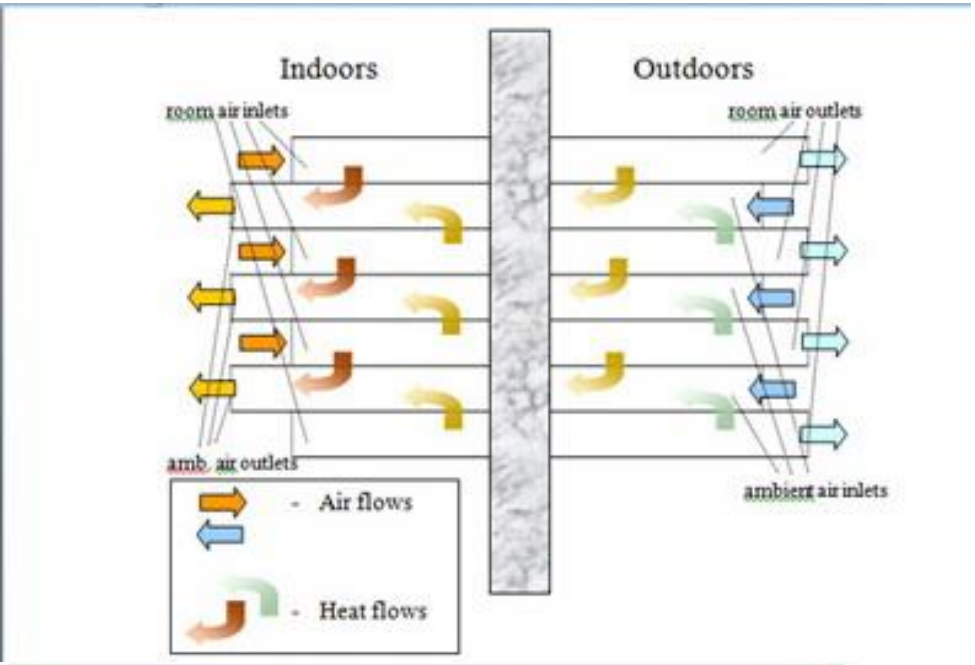
Current Standard:

New Construction: Stagnation of the industry…

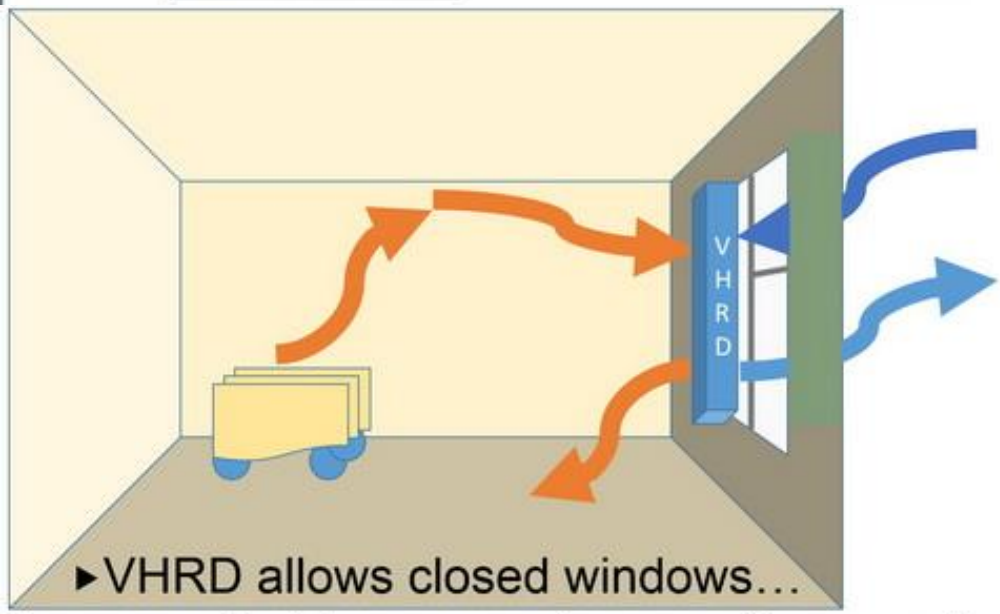


But the heating or cooling capacity will not be anymore enough – your expenses might be needed to multiply by a factor of 3-5!

2. The Gain

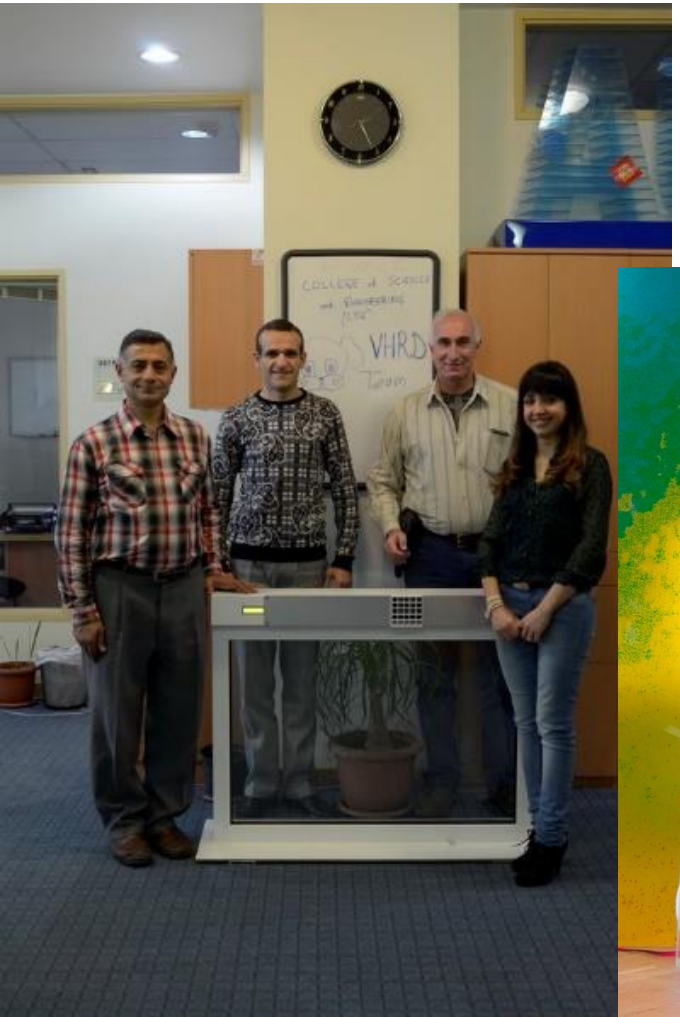


- **Uses heat recovery function to cut 85%+ of the energy cost.**
- **Compact, easy to install and modular.**
- **Does not require presence of expensive bidirectional mechanical system with ducting network.**
- **Affordable.**
- **Air tight design, blocking dust, pests, noise.**
- **Connected: Easy to monitor, control and maintain**



Now you are back to your normal consumption or even less!

Now



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